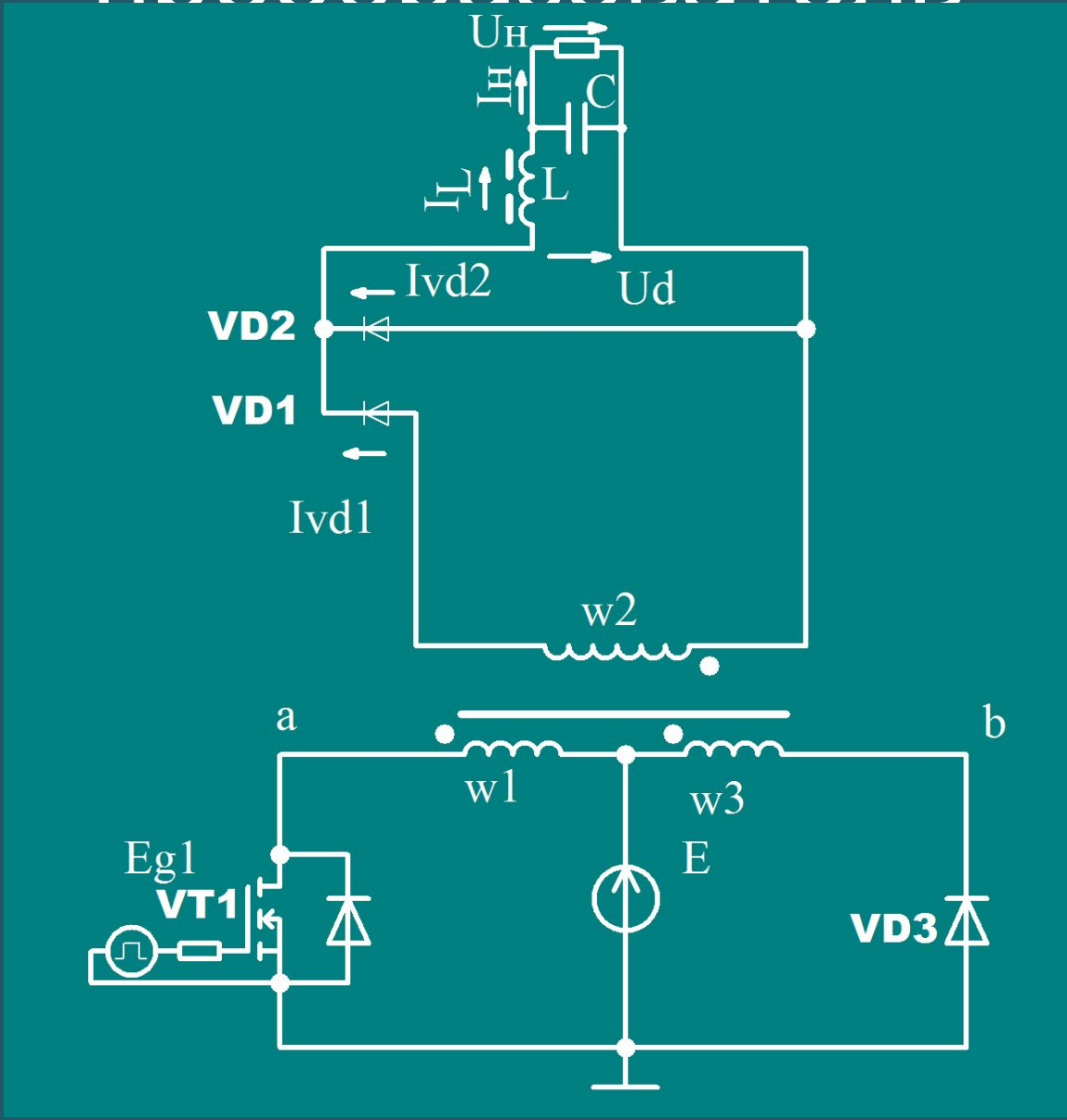
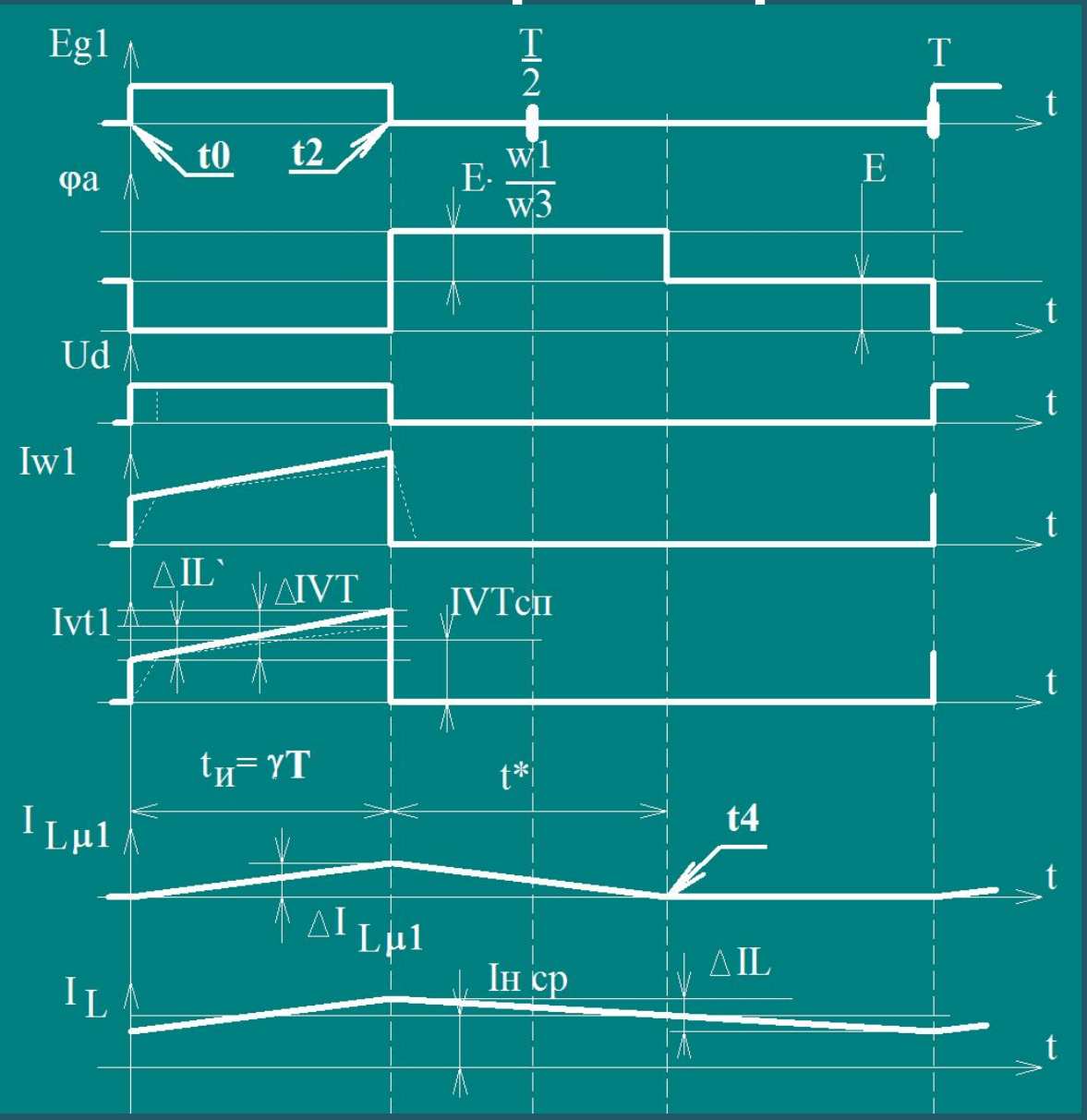
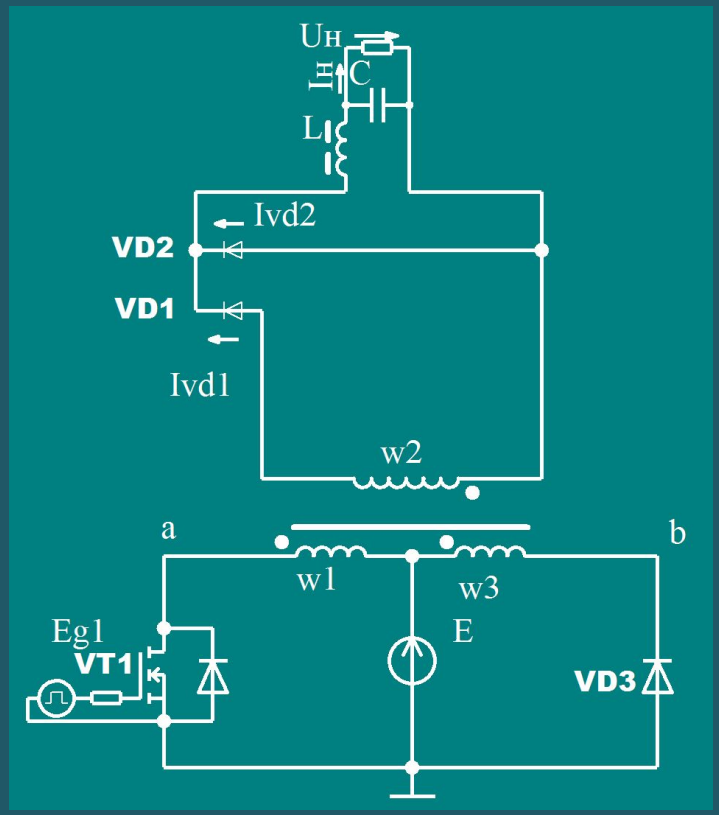
Однотактные преобразователи с потенциальной развязкой

Прямоходовой преобразователь

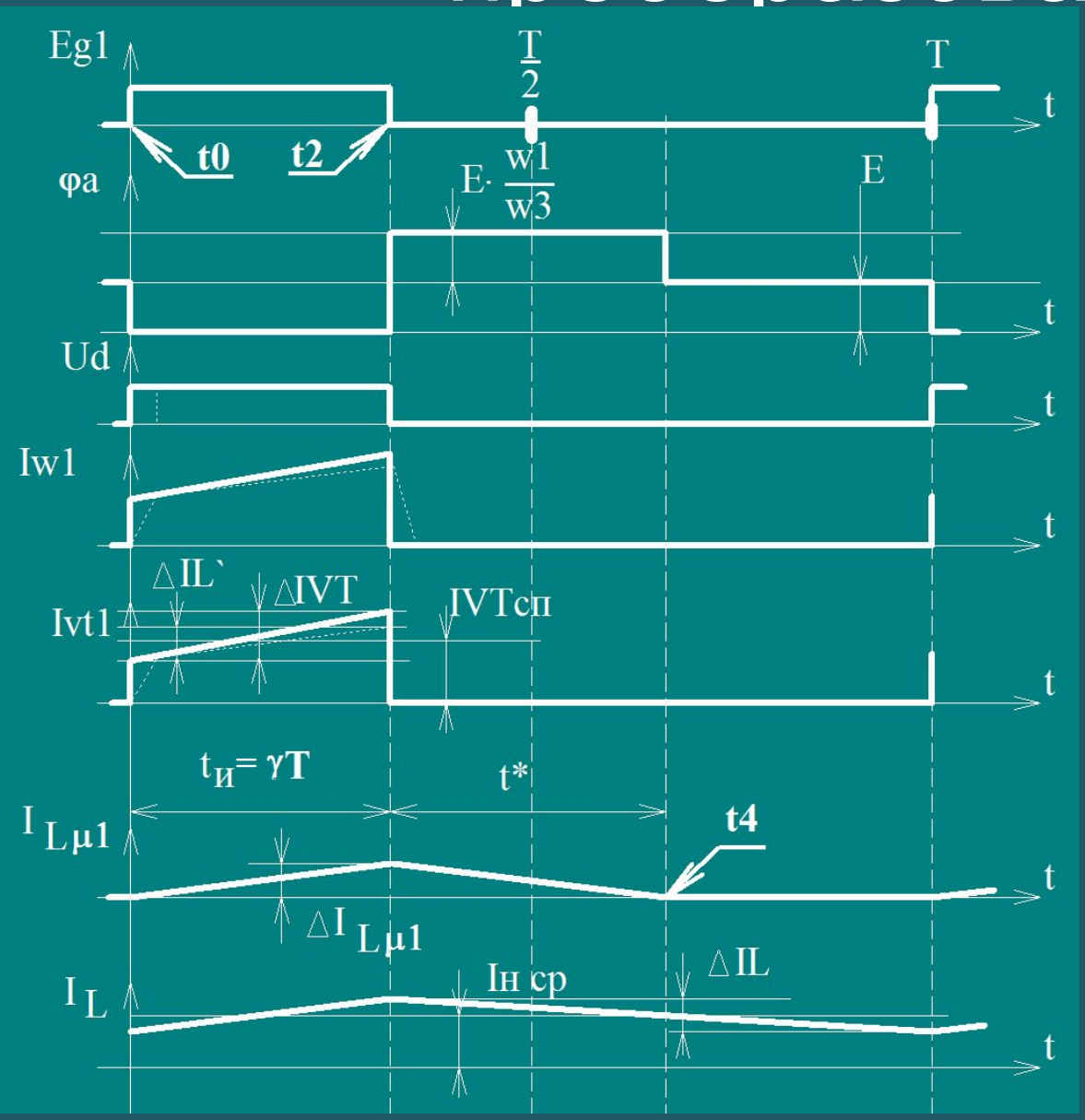


Прямоходовой преобразователь



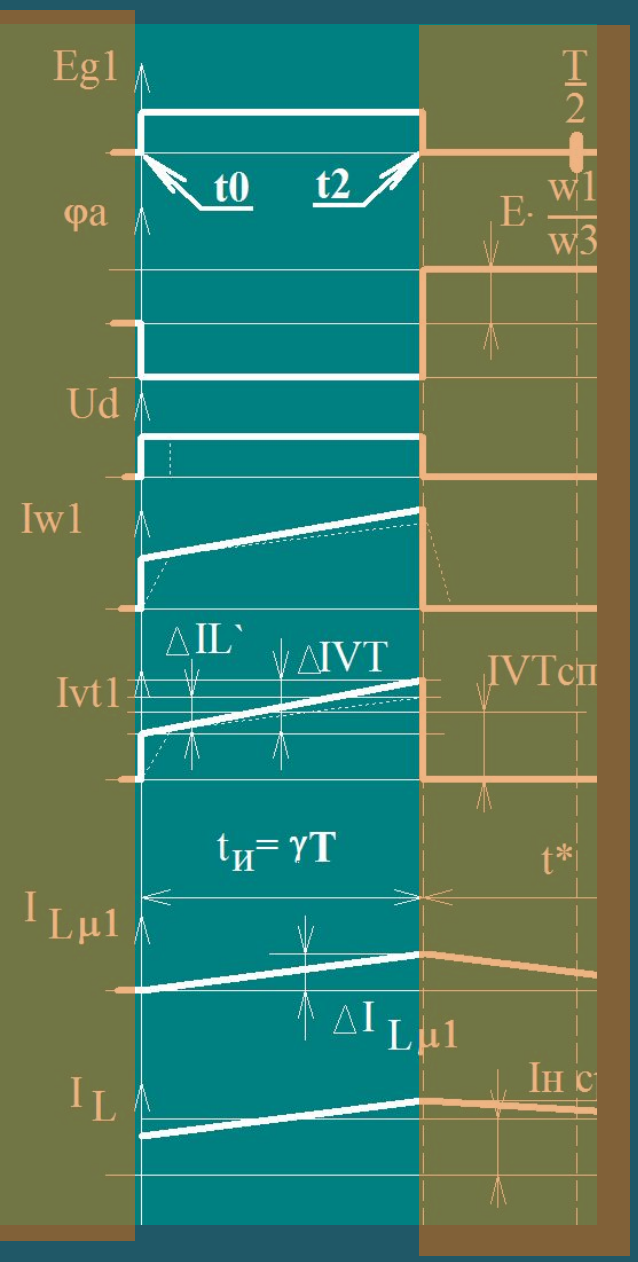


Прямоходовой преобразователь



E=290В, Ктр= w2/w1=0.5
w1/w3=1.2
Iн=10А, L→∞, γ=0.4
Lμ1=2мГн
f=100кГц
Найти среднее Uн
Найти t*
Построить ток Iw1

Интервал импульса



$$K_{тр} = \frac{w2}{w1}$$

$$\gamma = \frac{t_и}{T}$$

$$\frac{d\,I_L}{d\,t} = \frac{E \cdot K_{тр} - U_н}{L}$$

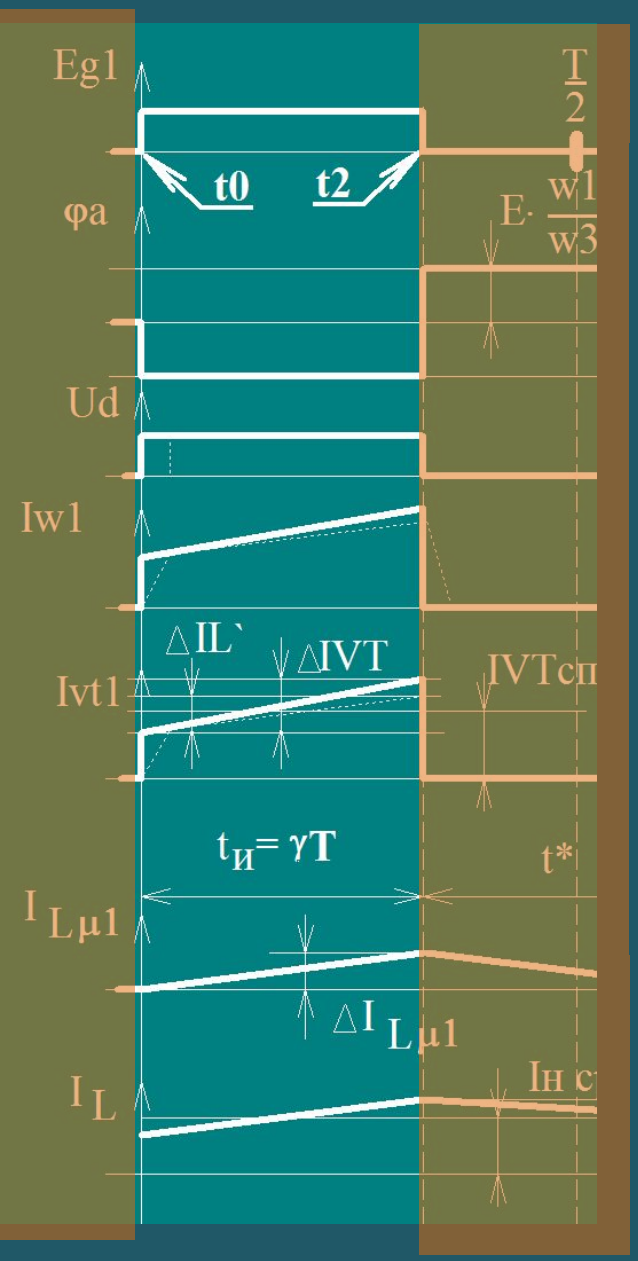
$$I_L(t) = I_{Lmin} + \frac{E \cdot K_{тр} - U_н}{L} \cdot t$$

$$I_L(tи) = I_{Lmin} + \frac{E \cdot K_{тр} - U_н}{L} \cdot t_и =$$

$$= I_{Lmin} + \frac{E \cdot K_{тр} - U_н}{L} \cdot \gamma \cdot T = I_{Lmax}$$

$$\Delta I_L = I_{Lmax} - I_{Lmin} = \frac{E \cdot K_{тр} - U_н}{L} \cdot t_и$$

Интервал импульса



$$\frac{d\,I_L}{d\,t} = \frac{(E - \Delta U_{VT}) \cdot K_{тр} - U_н - R_L \cdot I_L}{L}$$

$$I_L(t) = I_{Lmin} \cdot e^{-\frac{t}{\tau}} + \frac{(E - \Delta U_{VT}) \cdot K_{тр} - U_н}{R_L} \cdot \left(1 - e^{-\frac{t}{\tau}}\right) =$$

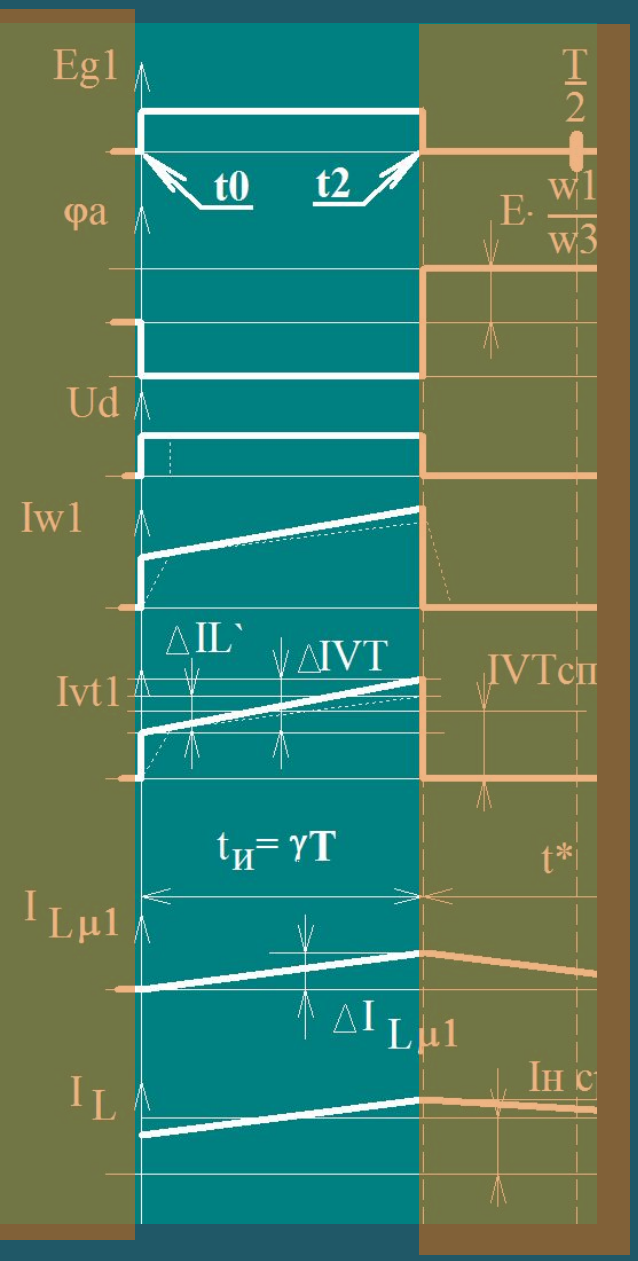
$$= \frac{(E - \Delta U_{VT}) \cdot K_{тр} - U_н}{R_L} + e^{-\frac{t}{\tau}} \cdot \left(I_{Lmin} - \frac{E - \Delta U_{VT} - U_н}{R_L}\right)$$

$$I_L(tи) = \frac{(E - \Delta U_{VT}) \cdot K_{тр} - U_н}{R_L} +$$

$$+ e^{-\frac{tи}{\tau}} \cdot \left(I_{Lmin} - \frac{(E - \Delta U_{VT}) \cdot K_{тр} - U_н}{R_L}\right) = I_{Lmax}$$

$$\tau = \frac{L}{R_L}$$

Интервал импульса

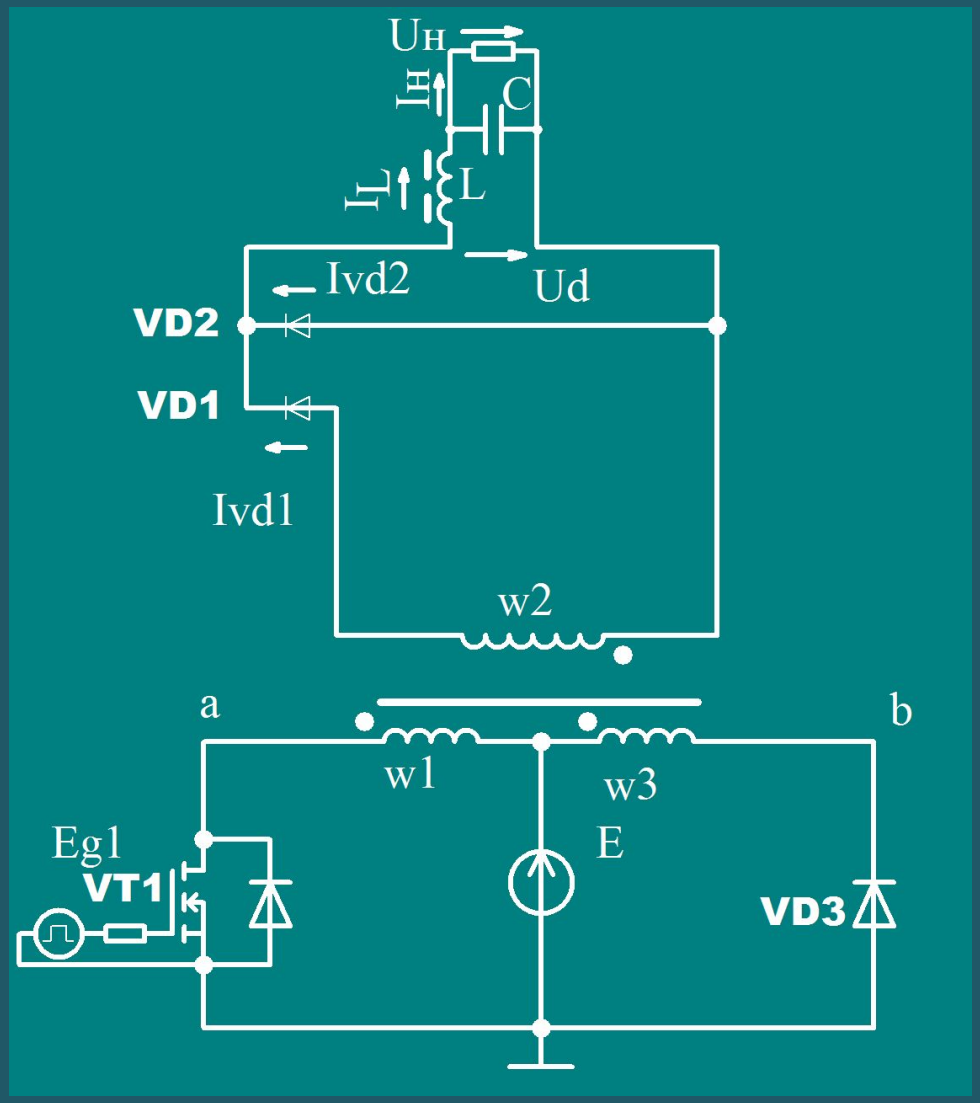


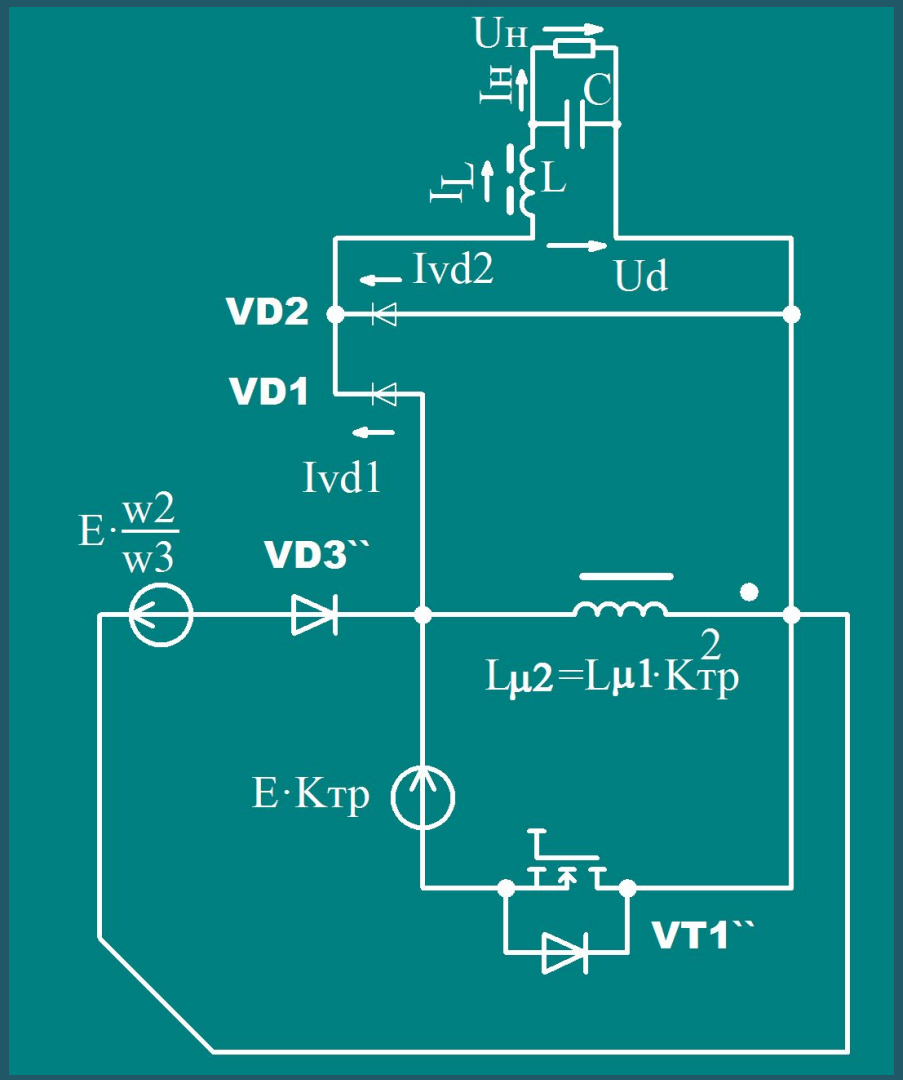
$$\frac{d\, I_{L\mu 1}}{d\, t} = \frac{E}{L\mu 1}$$

$$\Delta I_{L\mu 1} = I_{L\mu 1 max} = \frac{E}{L\mu 1} \cdot t_{\text{и}}$$

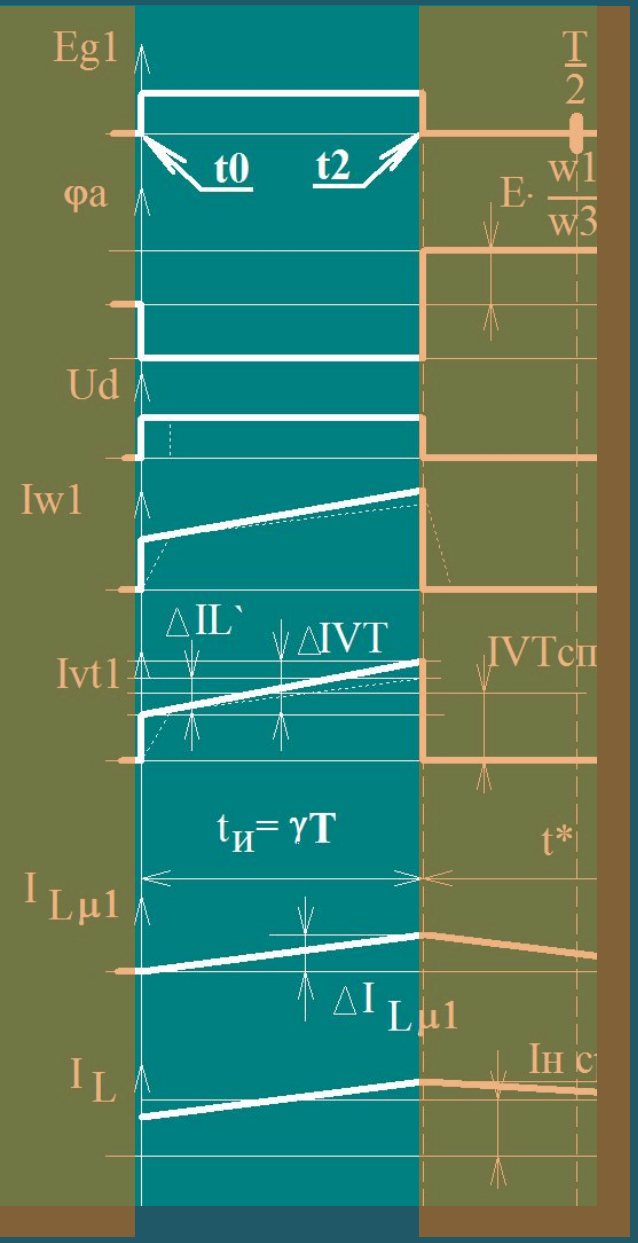
$$\Delta IVT = \Delta I_{L\mu 1} + \Delta I_L` = \Delta I_{L\mu 1} + \Delta I_L \cdot K_{\text{тр}}$$

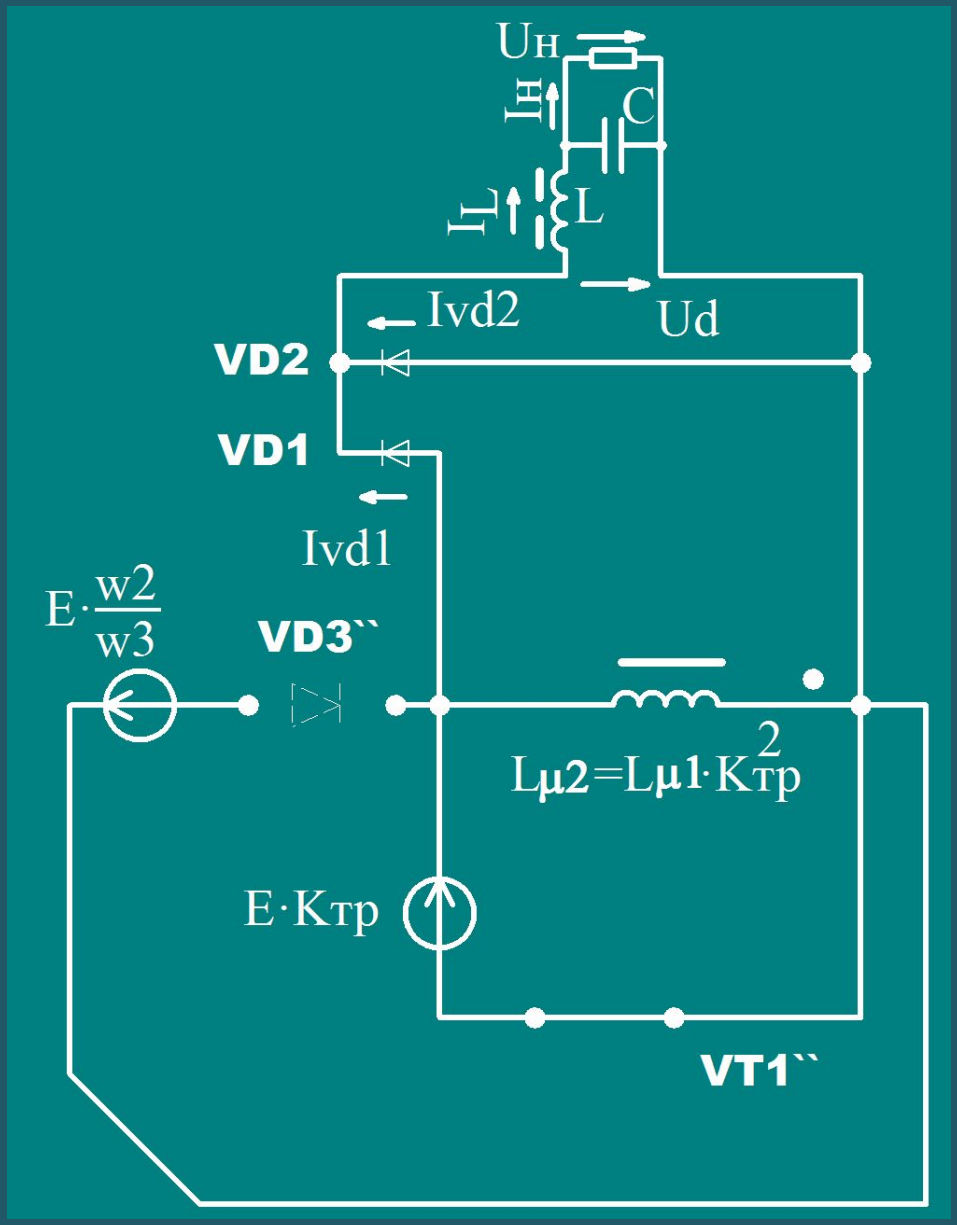
Интервал импульса



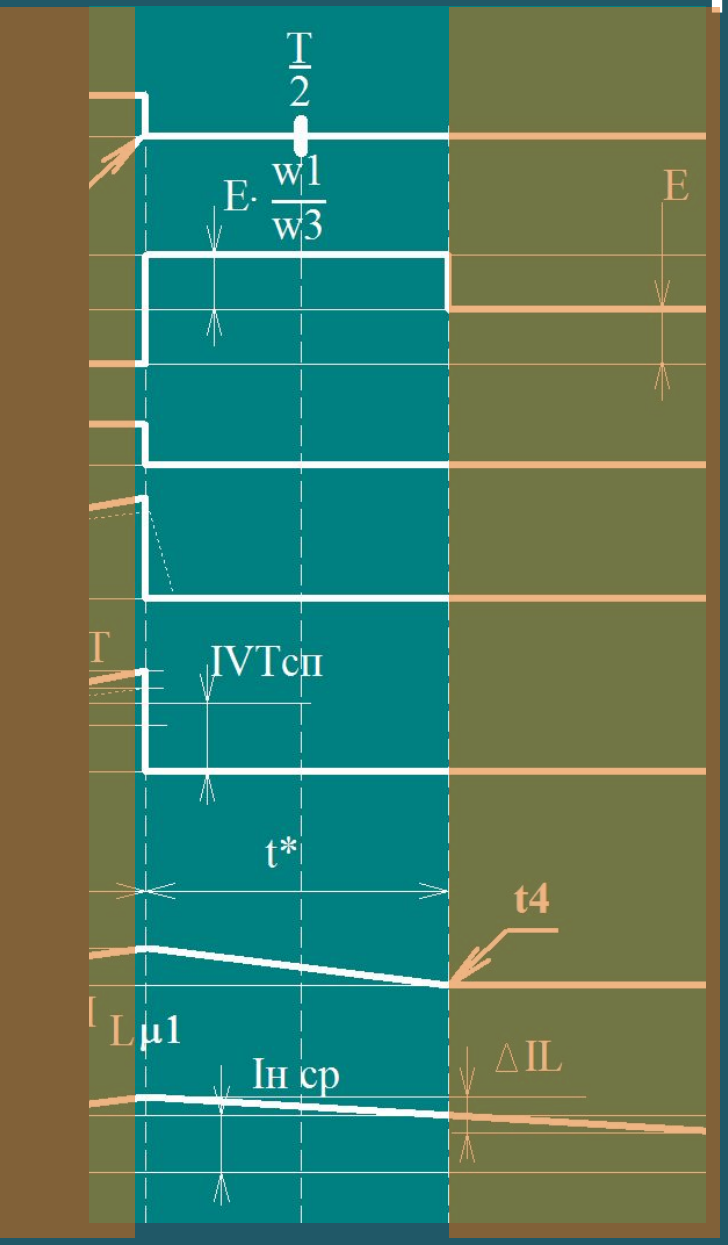


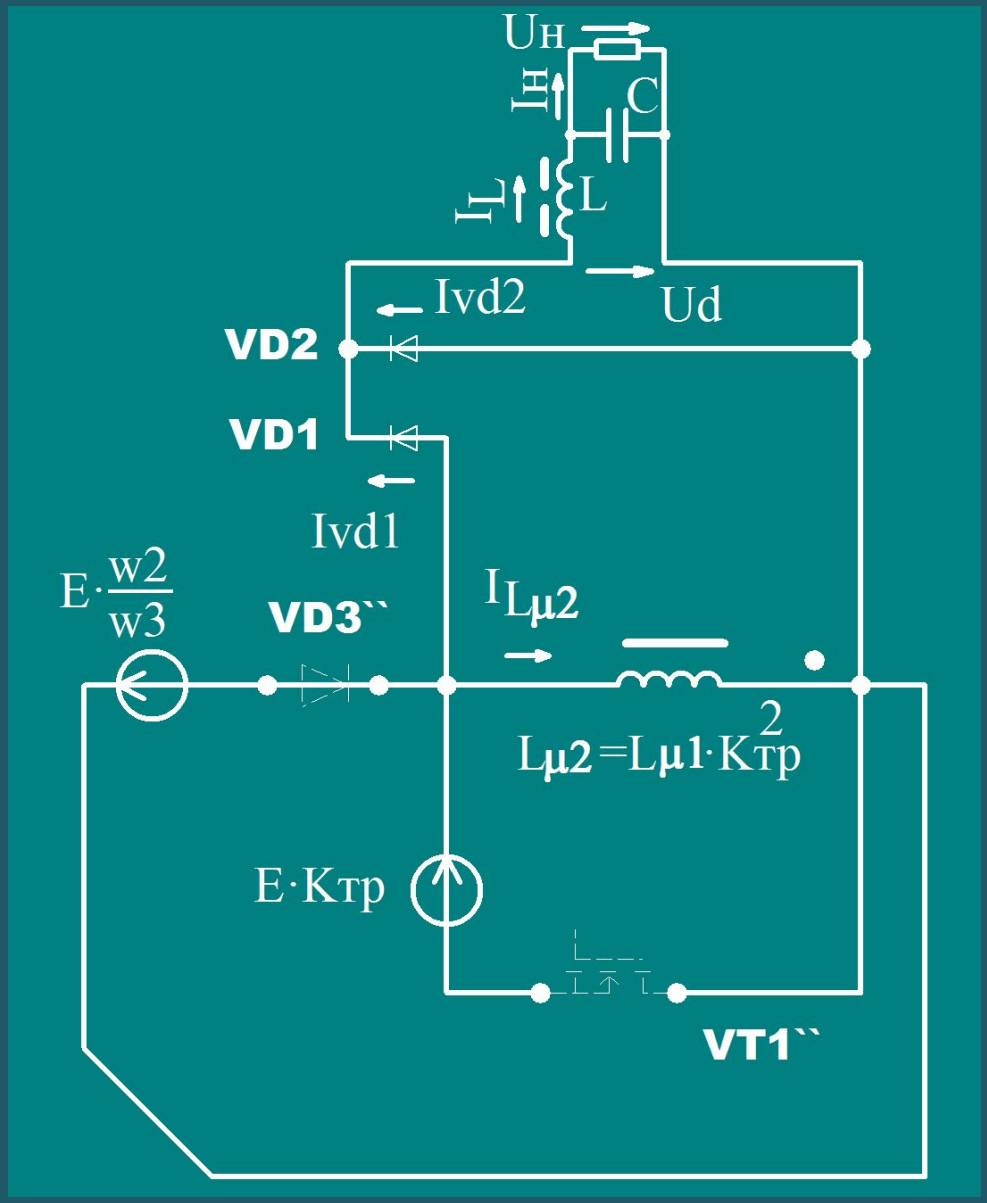
Интервал импульса



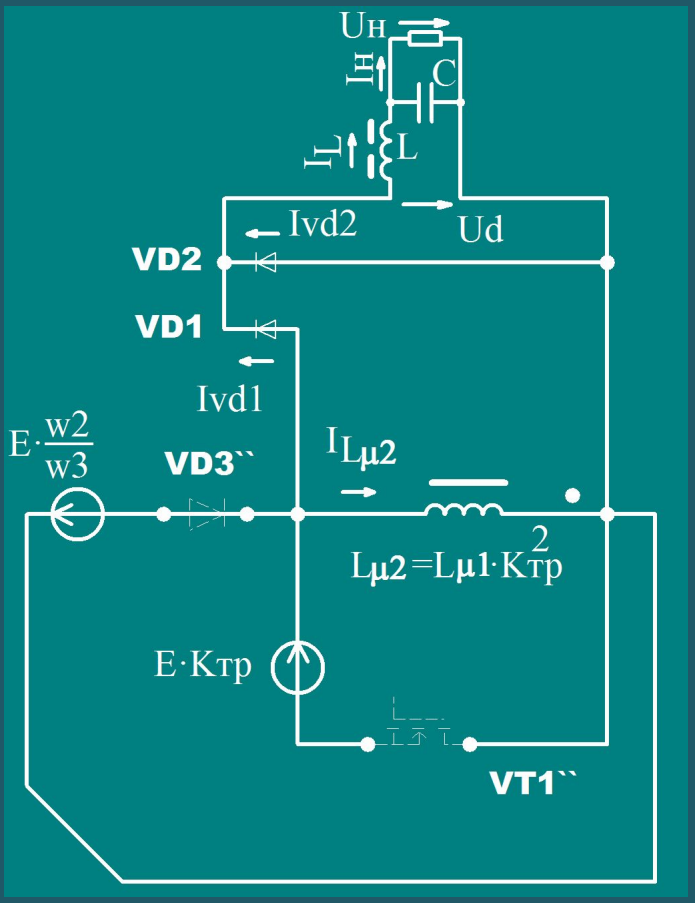


Интервал паузы: t*





Интервал паузы: t*



Обмотка w2:

$$\frac{d\,I_{L\mu 2}}{d\,t} = -\frac{E\cdot\frac{w2}{w3}}{L\mu 2} = -\frac{E\cdot\frac{w2}{w3}}{L\mu 1\cdot K_{\text{тр}}{}^2}$$

$$\Delta I_{L\mu 2} = I_{L\mu 2max} = \frac{I_{L\mu 1max}}{K_{\text{тр}}} = \frac{E}{L\mu 1\cdot K_{\text{тр}}}\cdot t_{\text{и}}$$

$$t^* = \frac{\Delta I_{L\mu 2}}{\left|\frac{d\,I_{L\mu 2}}{d\,t}\right|} = \frac{w3}{w2}\cdot K_{\text{тр}}\cdot t_{\text{и}} = \frac{w3}{w2}\cdot\frac{w2}{w1}\cdot t_{\text{и}} = \frac{w3}{w1}\cdot t_{\text{и}}$$

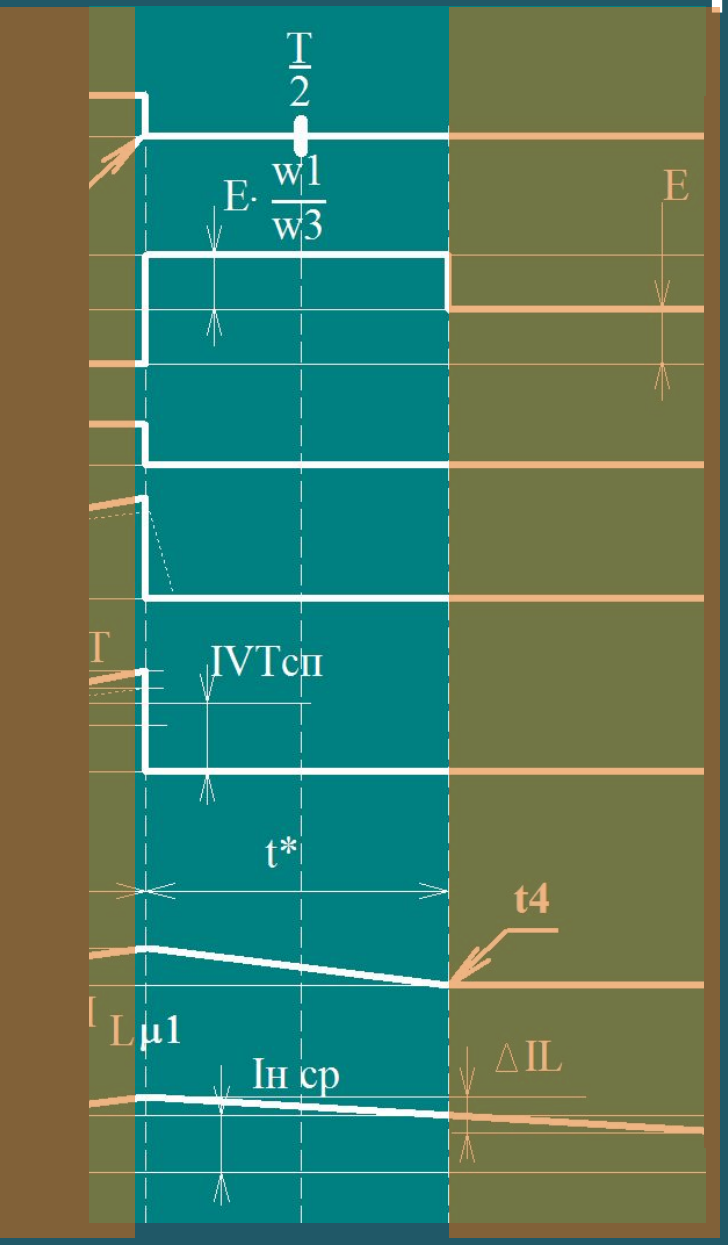
Обмотка w3:

$$\frac{d\,I_{L\mu 3}}{d\,t} = -\frac{E}{L\mu 3} = -\frac{E}{L\mu 1\cdot\left(\frac{w3}{w1}\right)^2}$$

$$\Delta I_{L\mu 3} = I_{L\mu 3max} = \frac{I_{L\mu 1max}}{\frac{w3}{w1}} = \frac{E}{L\mu 1\cdot\frac{w3}{w1}}\cdot t_{\text{и}}$$

$$t^* = \frac{\Delta I_{L\mu 3}}{\left|\frac{d\,I_{L\mu 3}}{d\,t}\right|} = \frac{w3}{w1}\cdot t_{\text{и}}$$

Интервал паузы: t*



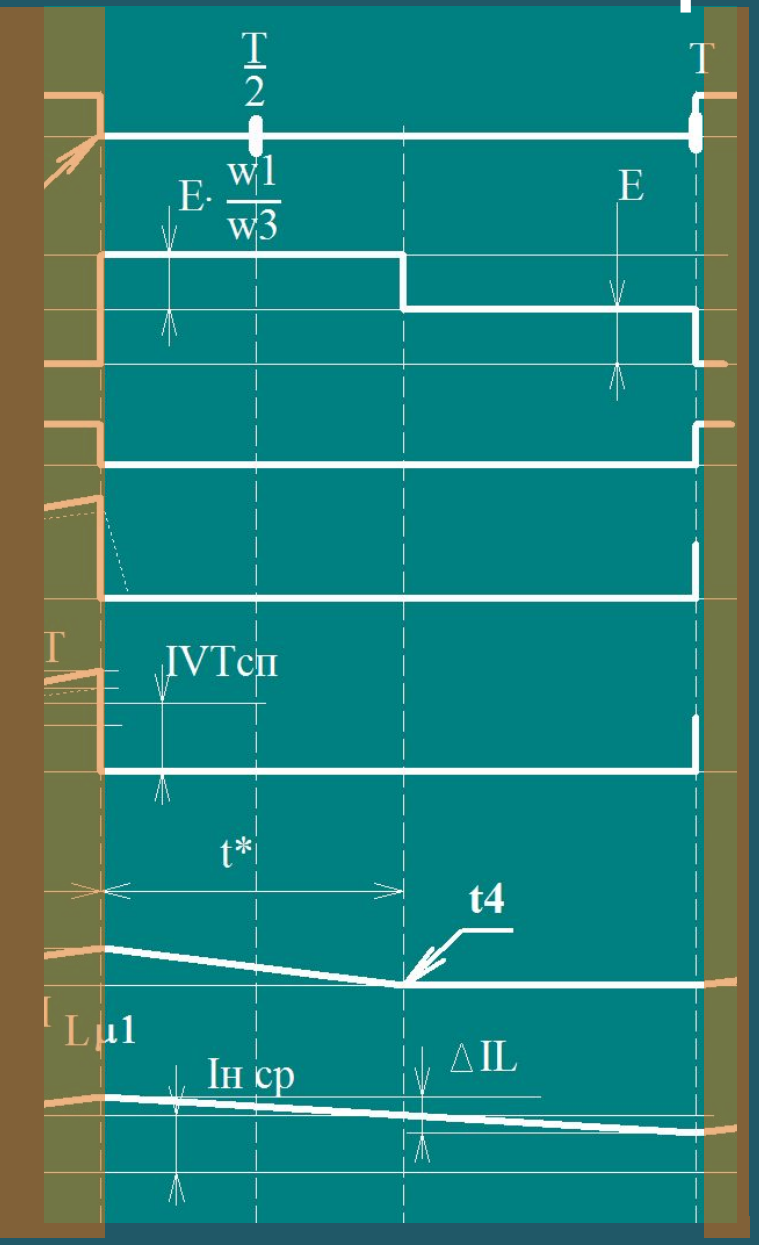
$$t^* + t_и < T \Rightarrow \left(\frac{w3}{w1} + 1\right) \cdot t_и < T$$

$$t_{иmax} = \gamma_{max} \cdot T < \frac{T}{\frac{w3 + w1}{w1}}$$

$$\gamma_{max} < \frac{w1}{w3 + w1}$$

$$\varphi_{amax} = U_{ds\,max} = E \cdot \left(\frac{w1}{w3} + 1\right) = E \cdot \frac{w1 + w3}{w3}$$

Интервал паузы t2-T



$$\frac{d\,I_L}{d\,t} = \frac{-U_н}{L}$$

$$I_L(t) = I_{Lmax} - \frac{U_н}{L} \cdot (t - t_и)$$

$$I_L(T) = I_{Lmax} - \frac{U_н}{L} \cdot (T - t_и) =$$

$$= I_{Lmax} - \frac{U_н}{L} \cdot (1 - \gamma) \cdot T = I_{Lmin} \quad (**)$$

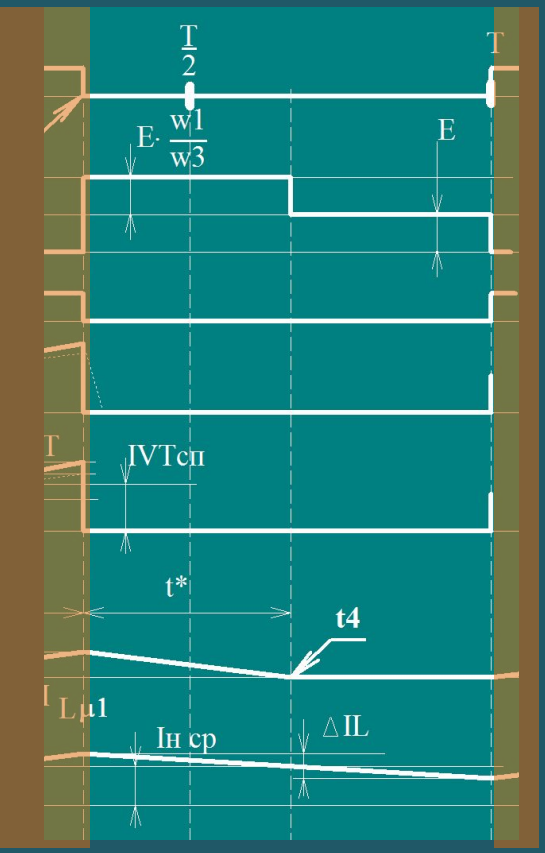
$$\Delta I_L = I_{Lmax} - I_{Lmin} = \frac{U_н}{L} \cdot (t - t_и) =$$

$$= \frac{U_н}{L} \cdot (1 - \gamma) \cdot T$$

$$I_{Lmin} + \frac{E \cdot K_{тр} - U_н}{L} \cdot \gamma \cdot T - \frac{U_н}{L} \cdot (1 - \gamma) \cdot T = I_{Lmin}$$

$$U_н = E \cdot K_{тр} \cdot \gamma$$

Интервал паузы t2-T



$$\frac{d\,I_L}{d\,t} = \frac{-\Delta U_{VD} - U_н - R_L \cdot I_L}{L}$$

$$I_L(t) = I_{Lmax} \cdot e^{-\frac{t-tи}{\tau}} + \frac{-\Delta U_{VD} - U_н}{R_L} \cdot \left(1 - e^{-\frac{t-tи}{\tau}}\right) =$$

$$= \frac{-\Delta U_{VD} - U_н}{R_L} + e^{-\frac{t-tи}{\tau}} \cdot \left(I_{Lmax} - \frac{-\Delta U_{VD} - U_н}{R_L}\right)$$

$$= \frac{-\Delta U_{VD} - U_н}{R_L} + e^{-\frac{t-tи}{\tau}} \cdot$$

$$\cdot \left(\frac{E - \Delta U_{VT} - U_н}{R_L} + e^{-\frac{tи}{\tau}} \cdot \left(I_{Lmin} - \frac{E - \Delta U_{VT} - U_н}{R_L}\right) - \frac{-\Delta U_{VD} - U_н}{R_L}\right) =$$

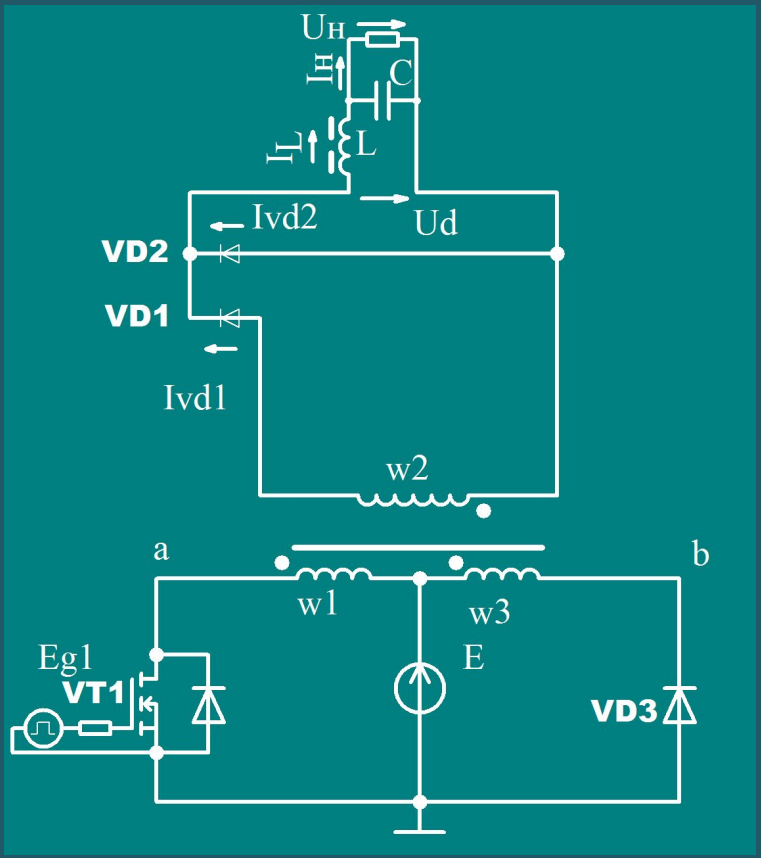
$$= \frac{-\Delta U_{VD} - U_н}{R_L} + e^{-\frac{t-tи}{\tau}} \cdot$$

$$\cdot \left(\frac{E - \Delta U_{VD} - \Delta U_{VT}}{R_L} + e^{-\frac{tи}{\tau}} \cdot \left(I_{Lmin} - \frac{E - \Delta U_{VT} - U_н}{R_L}\right)\right)$$

$$I_L(T) = I_{Lmax} \cdot e^{-\frac{T-tи}{\tau}} + \frac{-\Delta U_{VD} - U_н}{R_L} \cdot \left(1 - e^{-\frac{T-tи}{\tau}}\right) =$$

$$= \frac{-\Delta U_{VD} - U_н}{R_L} + e^{-\frac{T-tи}{\tau}} \cdot \left(I_{Lmax} - \frac{-\Delta U_{VD} - U_н}{R_L}\right)$$

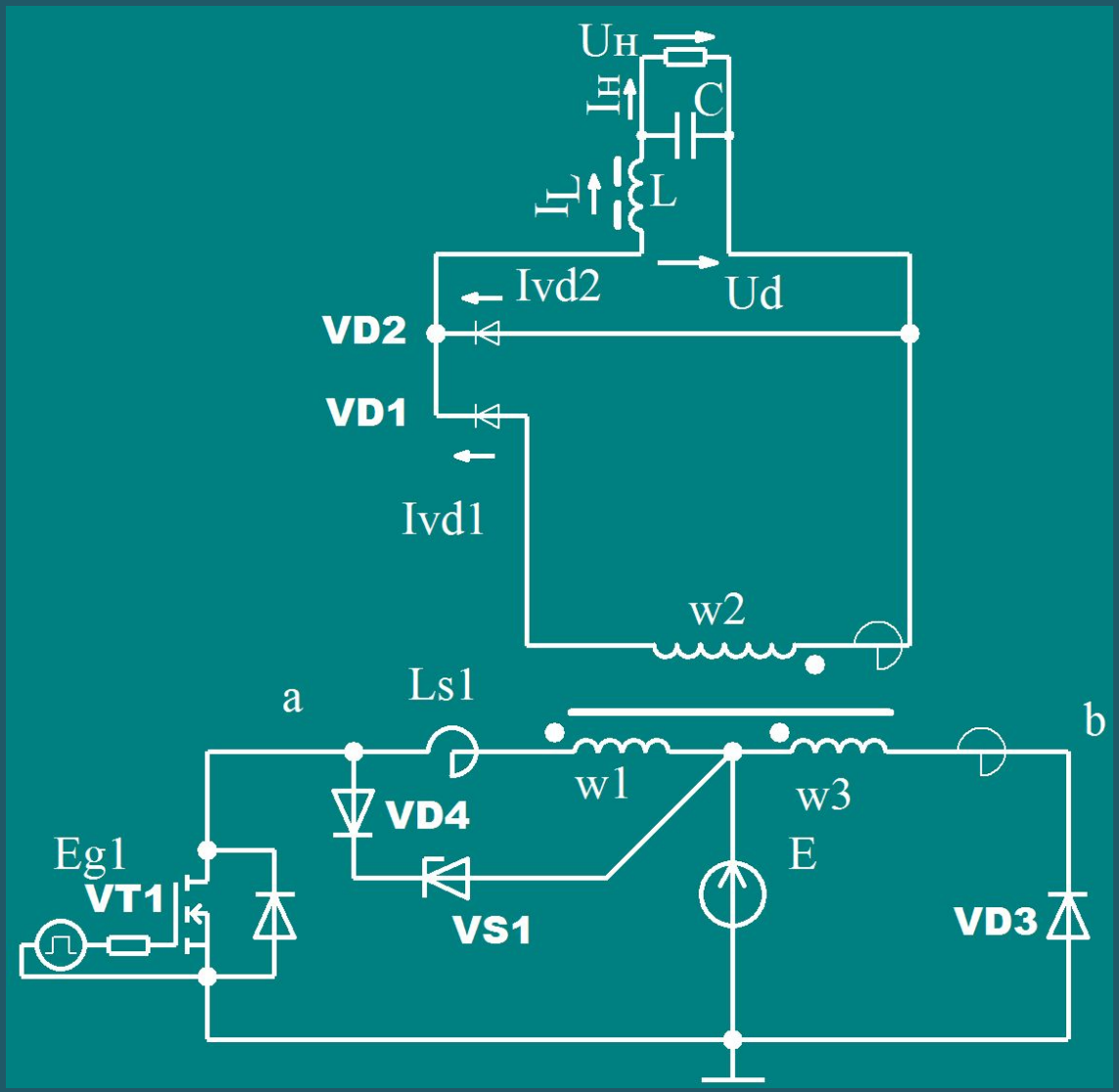
Напряжение нагрузки



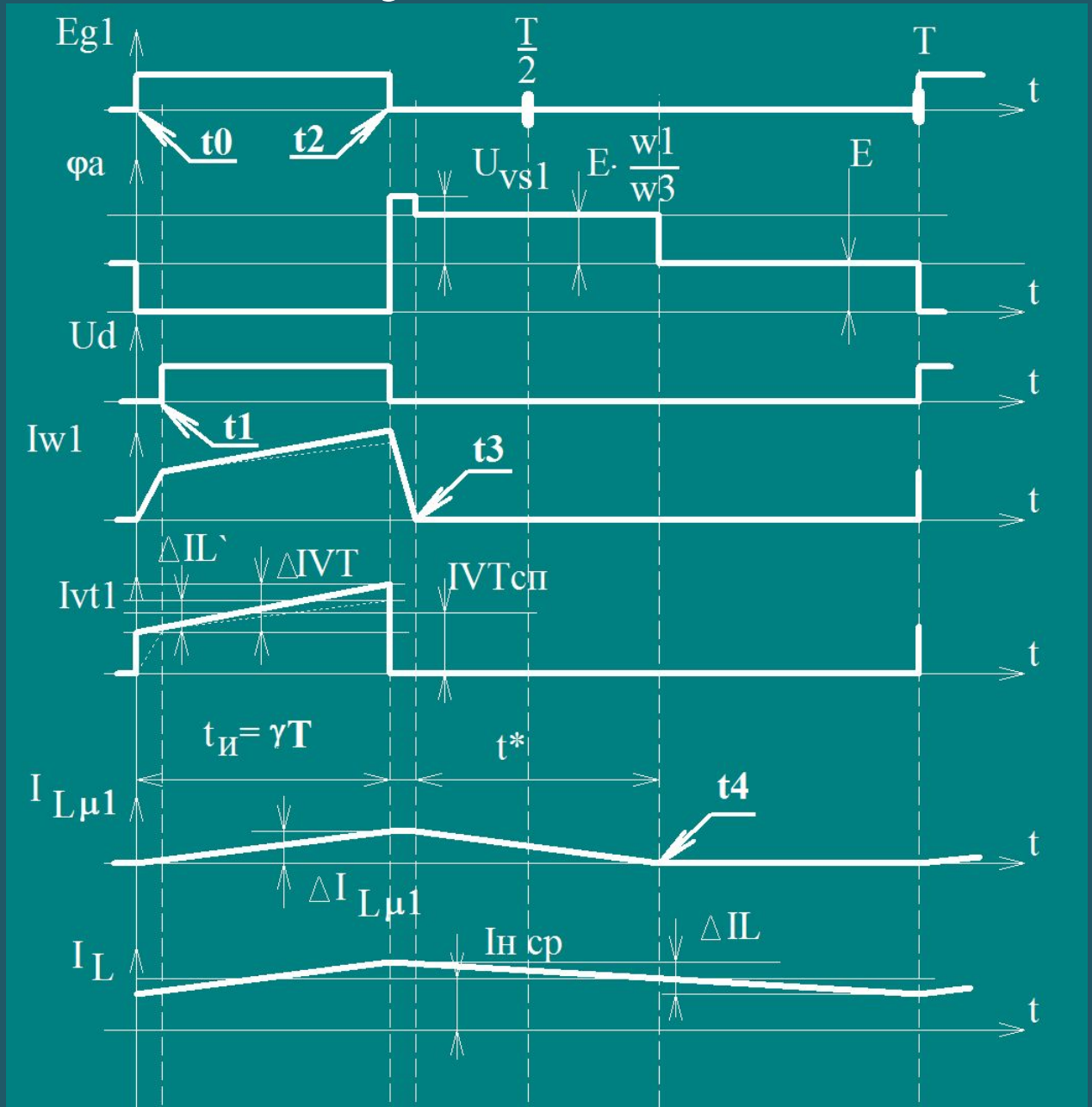
$$U_{\text{н}} = (E - \Delta U_{VT}) \cdot K_{\text{тр}} \cdot \gamma - \Delta U_{VD} - I_{L\text{ср}} \cdot R_L =$$

$$= (E - \Delta U_{VT}) \cdot K_{\text{тр}} \cdot \gamma - \Delta U_{VD} - I_{\text{нср}} \cdot R_L$$

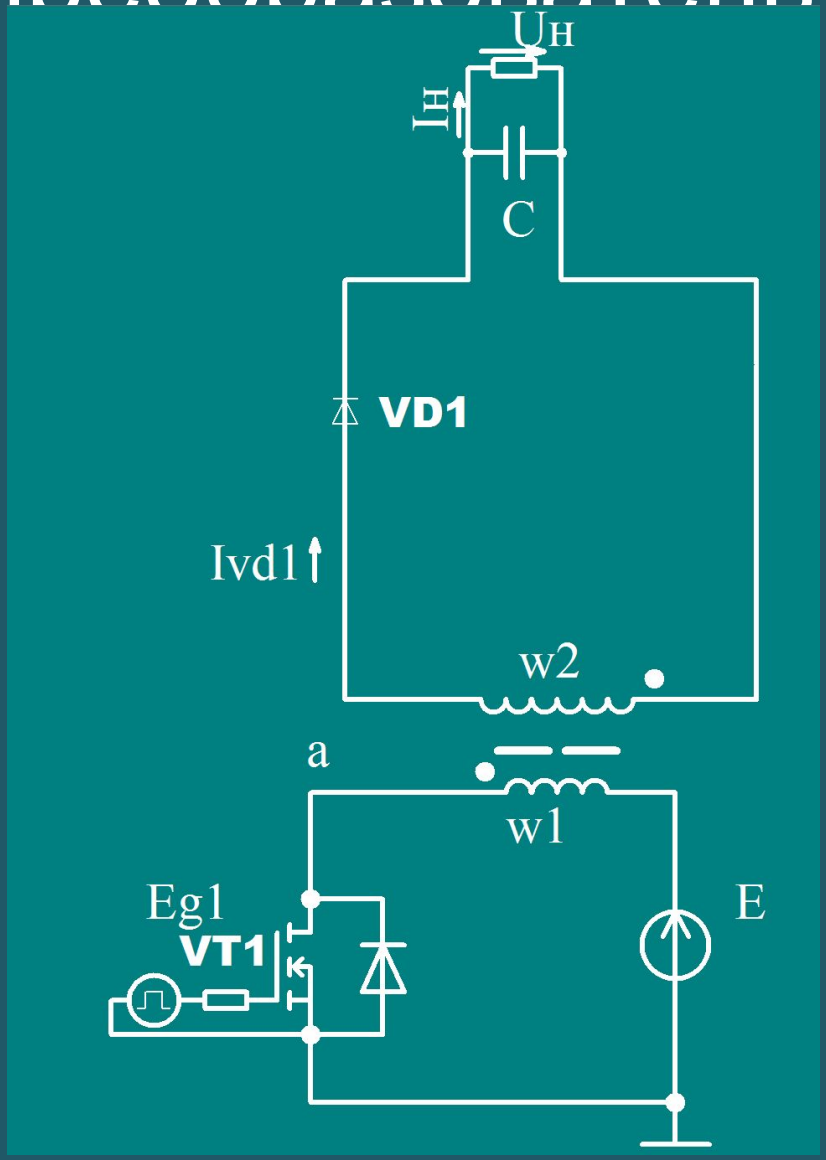
С учетом Ls


Uн
Iн
C
IL
L
Ivd2
Ud
VD2
VD1
Ivd1
w2
a
Ls1
b
w1
w3
VD4
Eg1
VT1
VS1
E
VD3

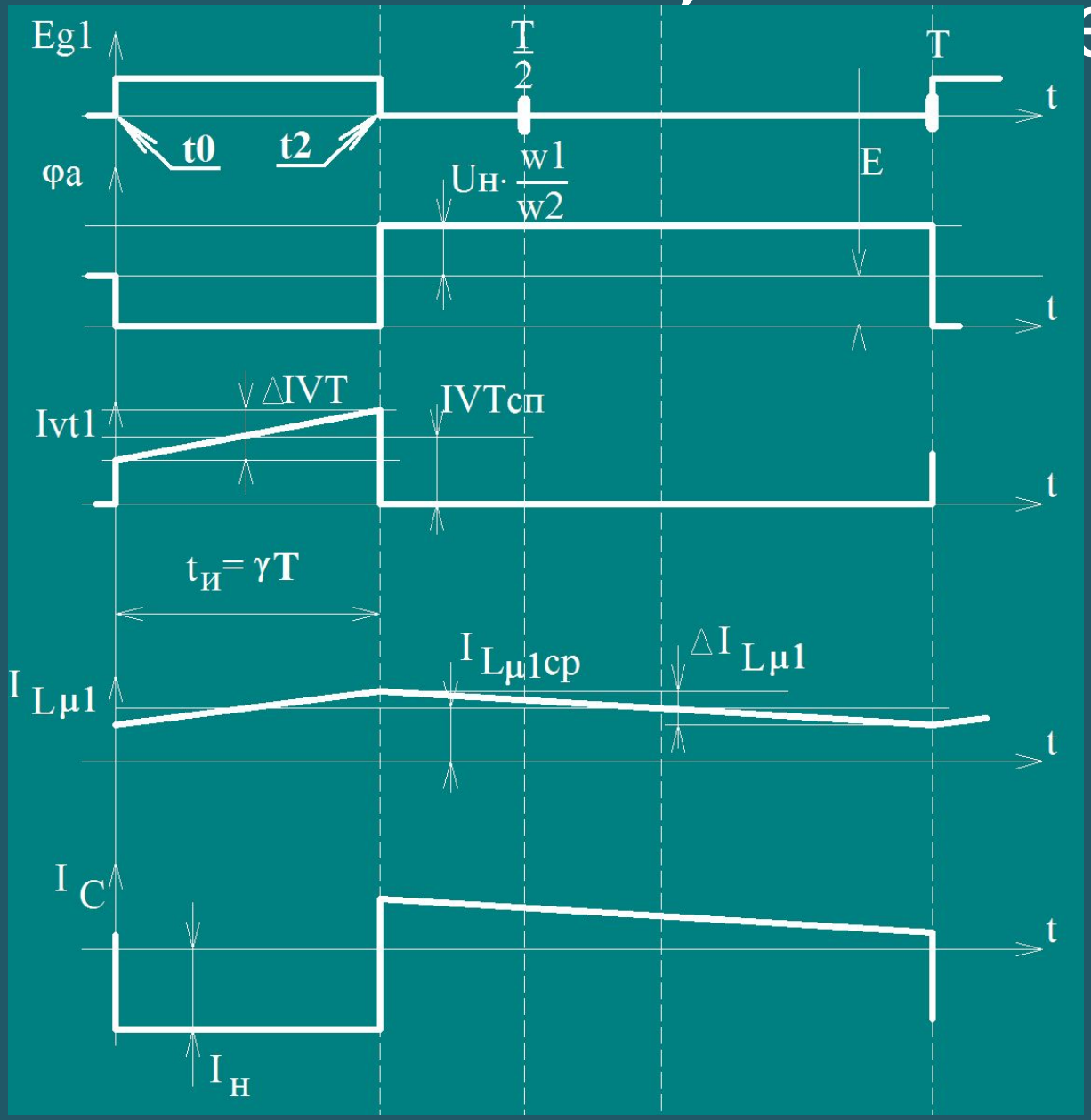
С учетом Ls

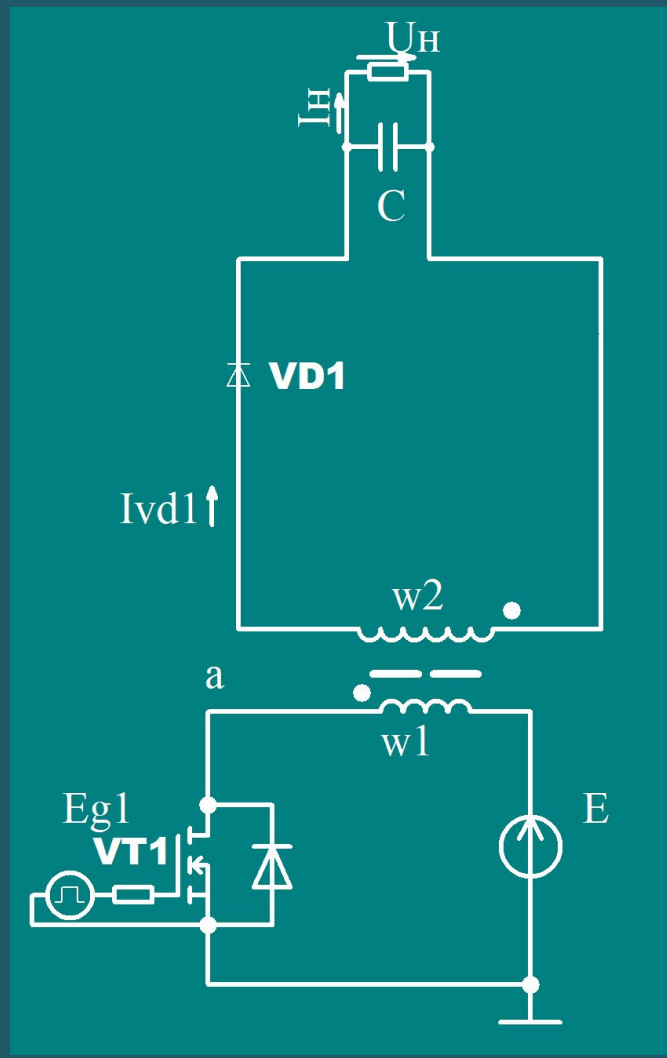

Eg1
T/2
T
t
t0
t2
φa
Uvs1
E· w1/w3
E
Ud
t1
Iw1
t3
ΔIL`
ΔIVT
Ivt1
IVTсп
tи= γT
t*
I Lμ1
t4
ΔI Lμ1
I L
Iн ср
ΔIL

Обратноходовой преобразователь

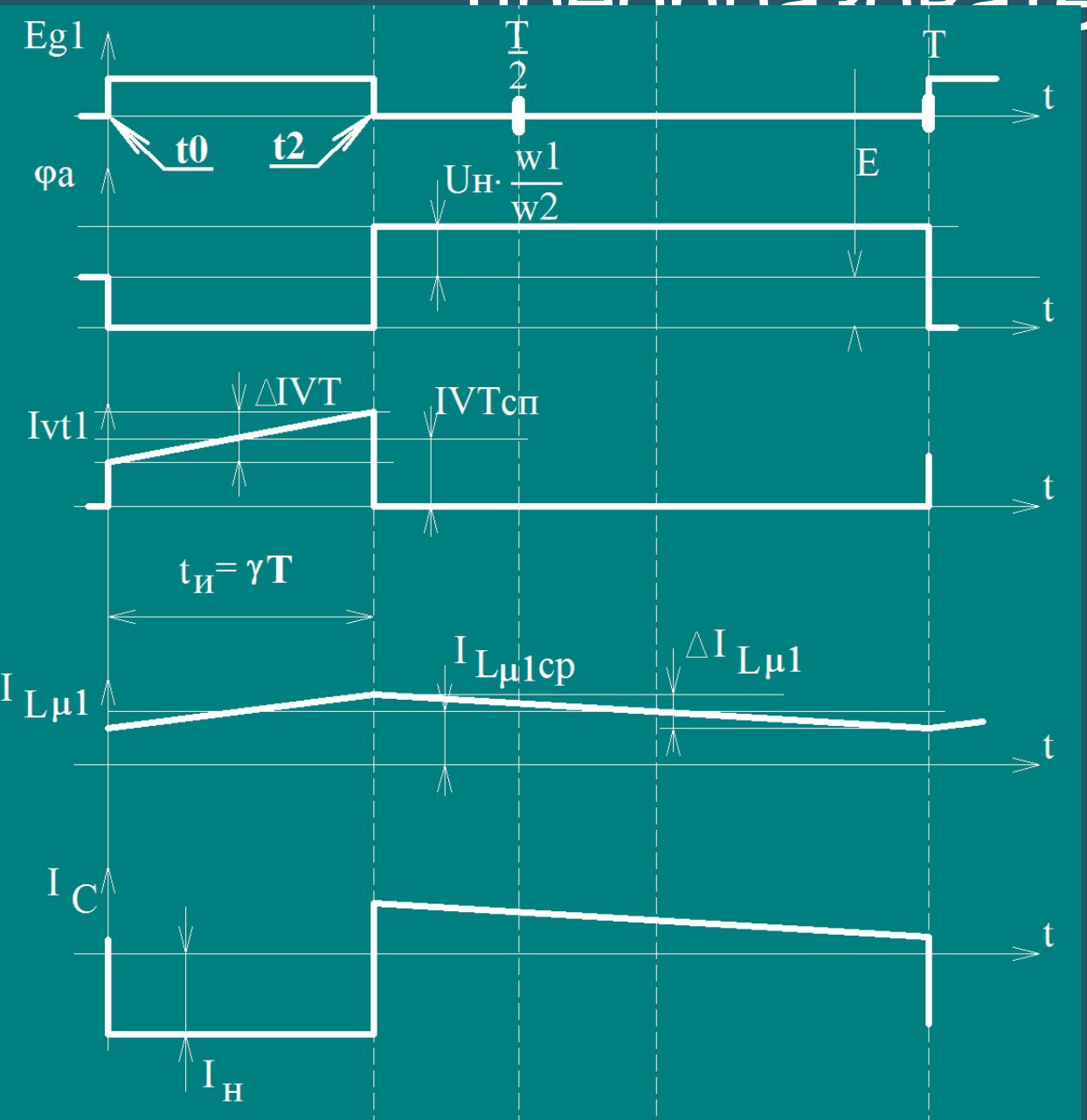


Обратноходовой
ель



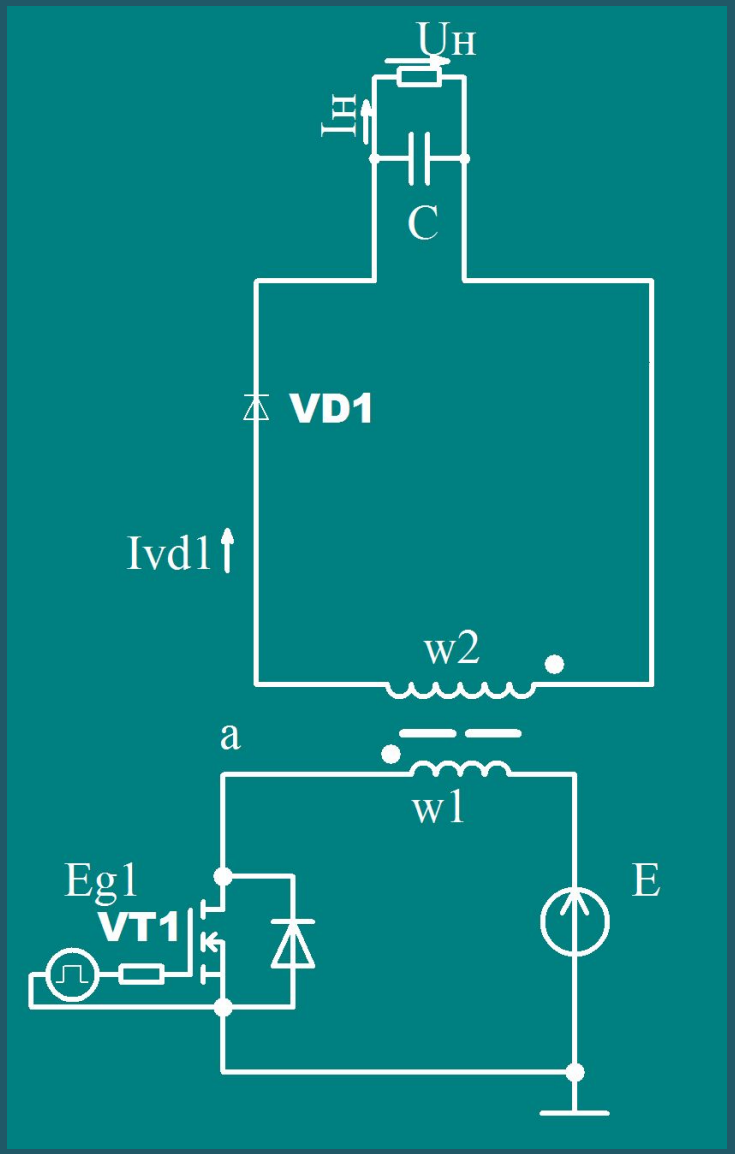


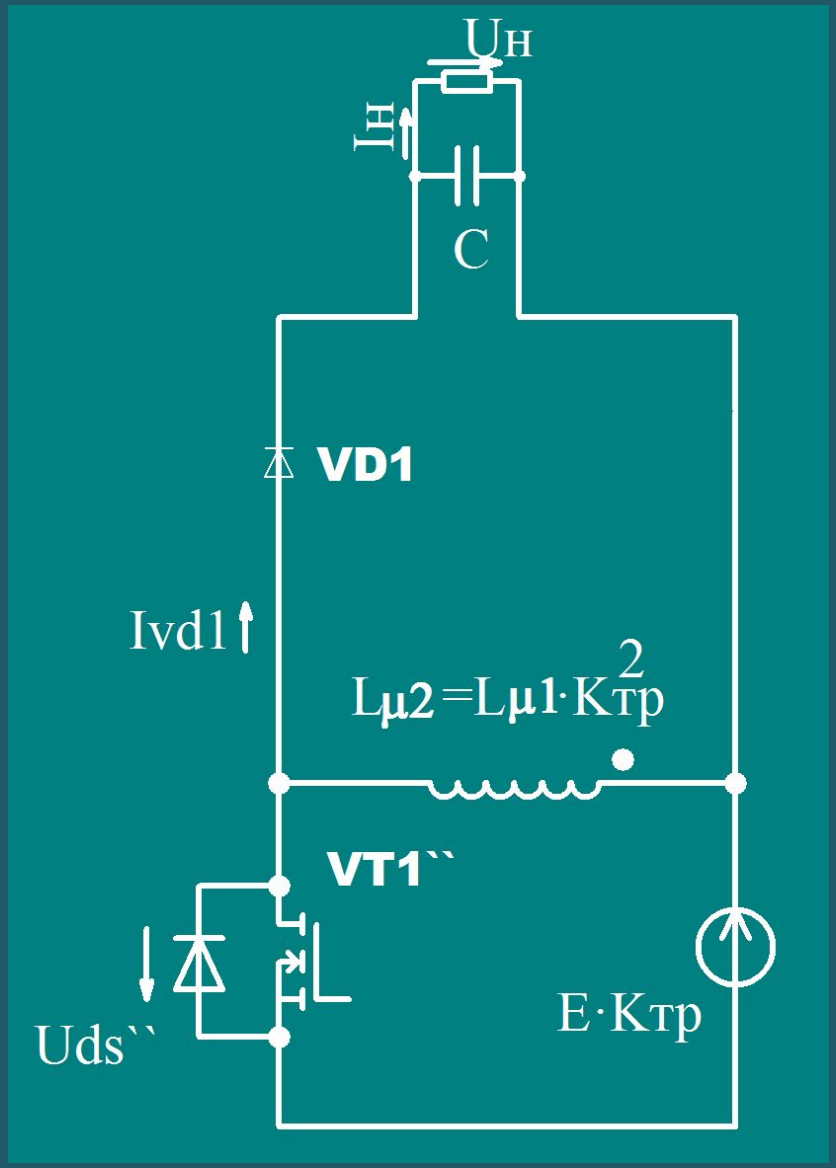
Обратноходовой преобразователь



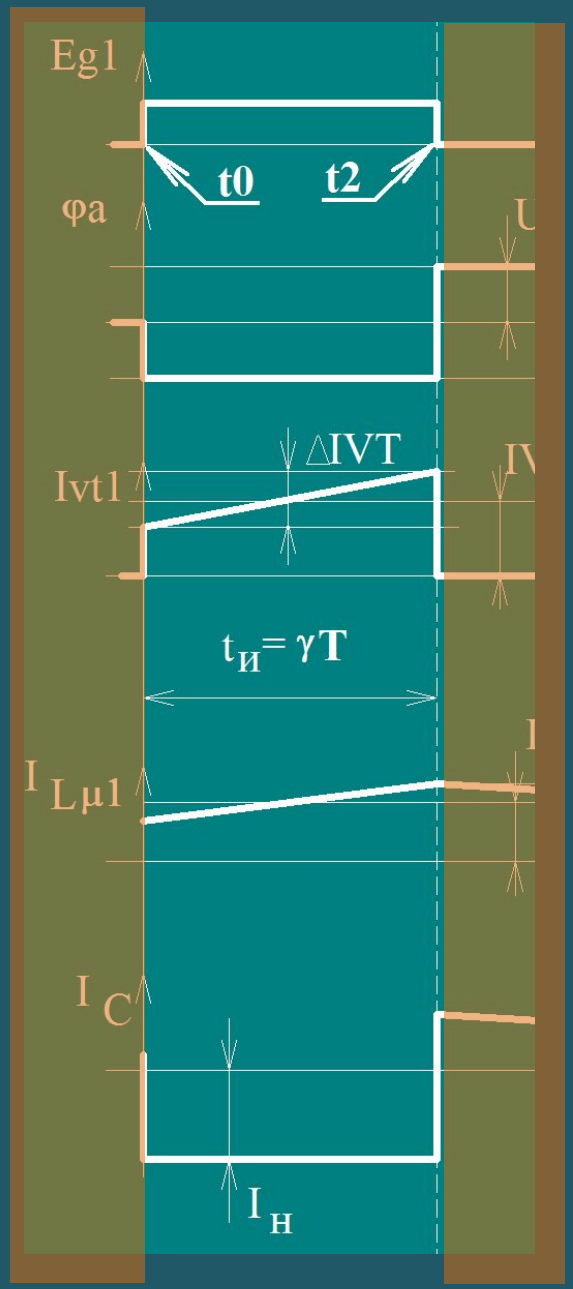
E=310В, Ктр= w2/w1=0.5
Iн=10А, L→∞, γ=0.7
Lμ1=2мГн
f=100кГц
Найти среднее Uн
Построить ток Iw1

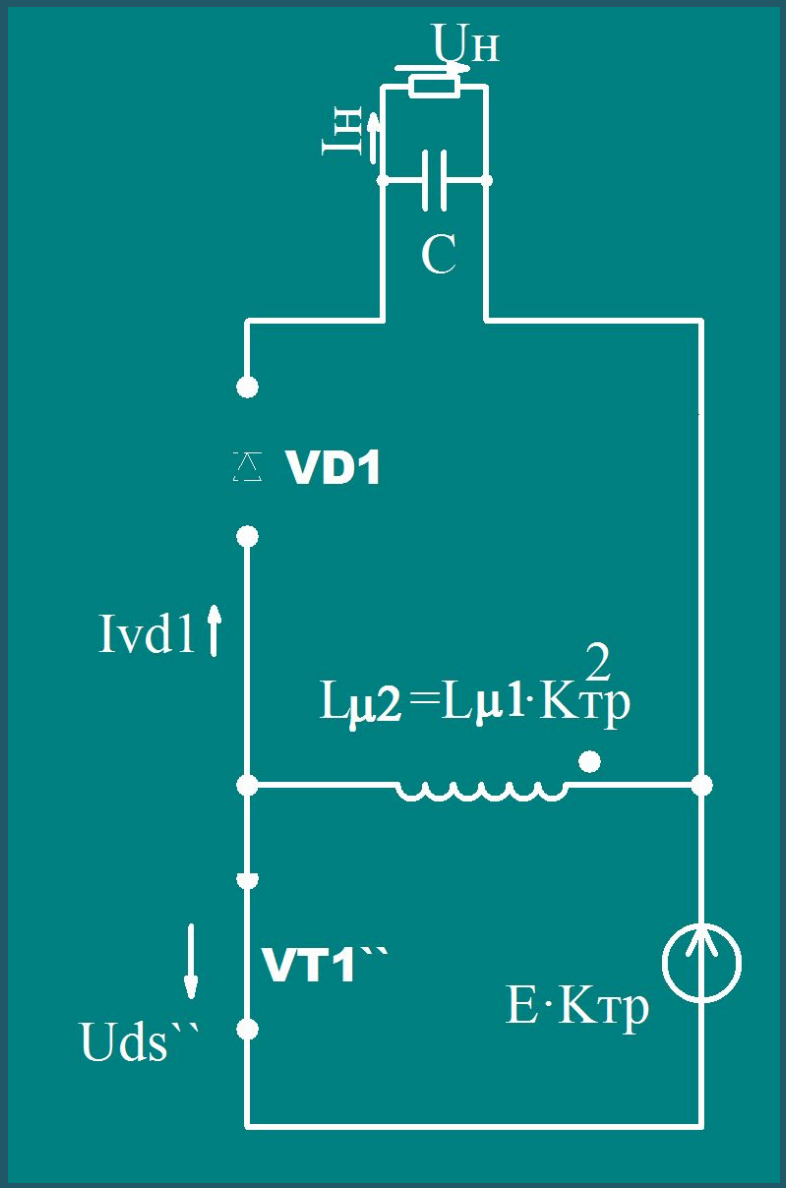
Эквивалентная схема



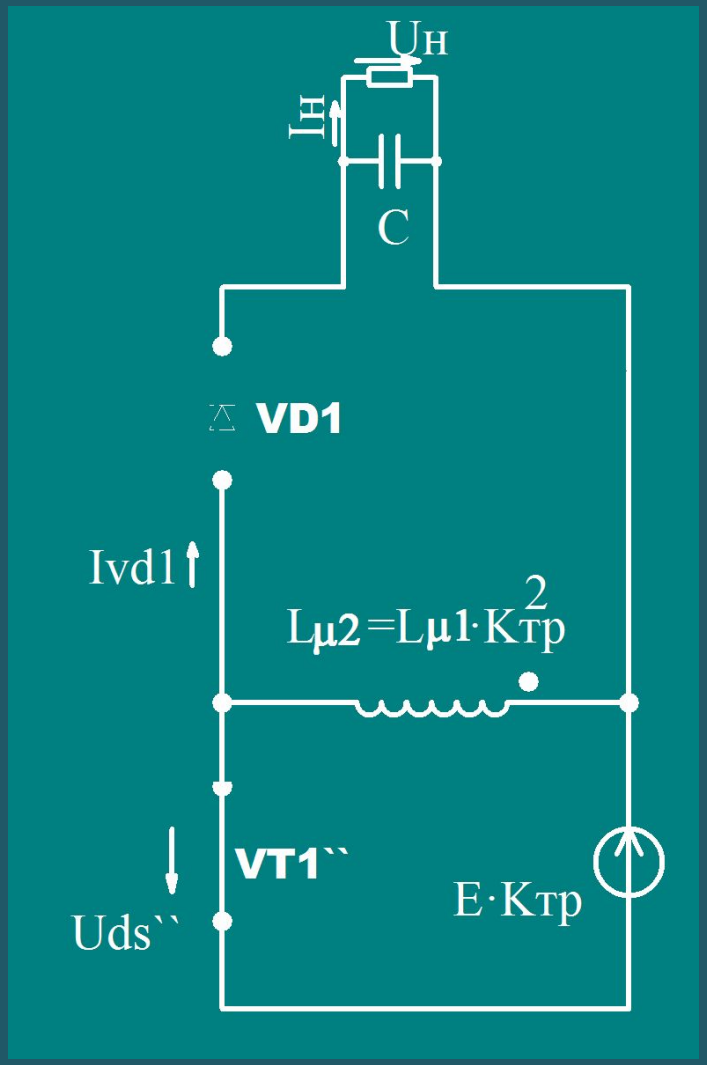


Интервал импульса





Интервал импульса



$$K_{тр} = \frac{w2}{w1}$$

$$\gamma = \frac{t_и}{T}$$

$$I_{L\mu 2} = I_{L\mu 1} \cdot {K_{тр}}^2$$

$$\frac{d\, I_{L\mu 2}}{d\, t} = \frac{E \cdot K_{тр}}{L\mu 2}$$

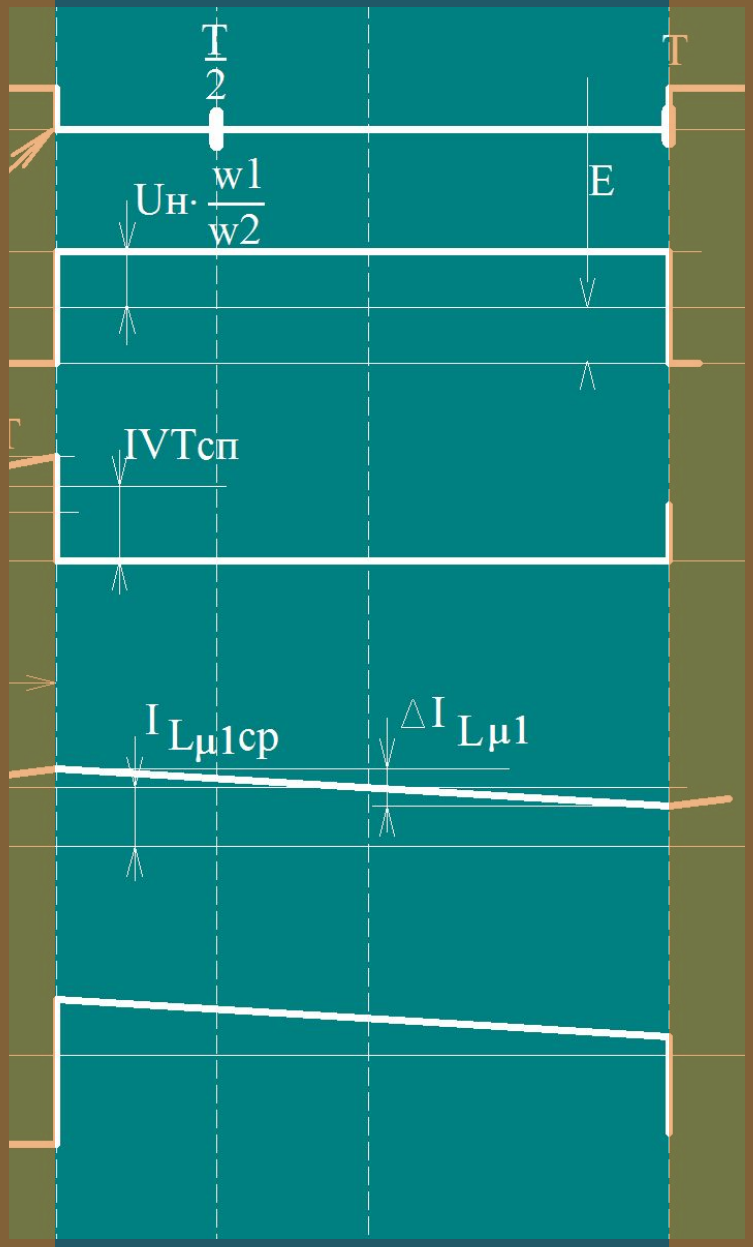
$$I_{L\mu 2}(t) = I_{L\mu 2min} + \frac{E \cdot K_{тр}}{L\mu 2} \cdot t$$

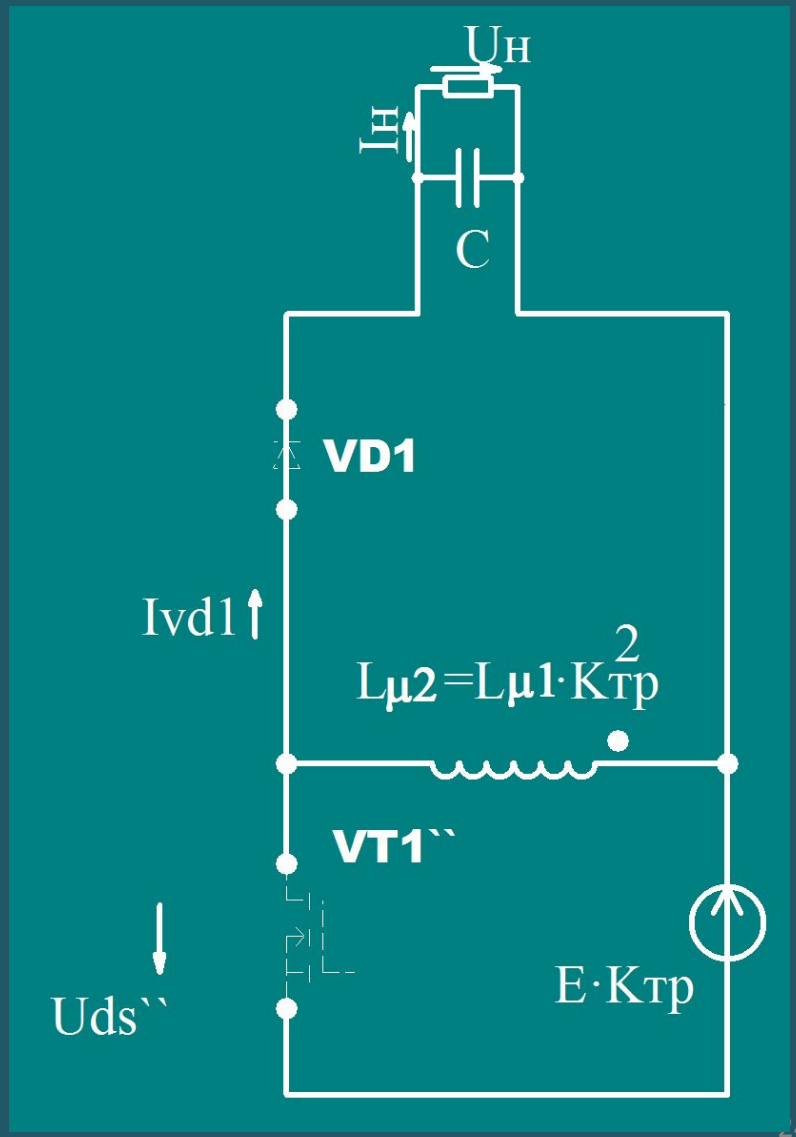
$$I_{L\mu 2}(tи) = I_{L\mu 2min} + \frac{E \cdot K_{тр}}{L\mu 2} \cdot t_и =$$

$$= I_{L\mu 2min} + \frac{E \cdot K_{тр}}{L} \cdot \gamma \cdot T = I_{L\mu 2max} \quad (***)$$

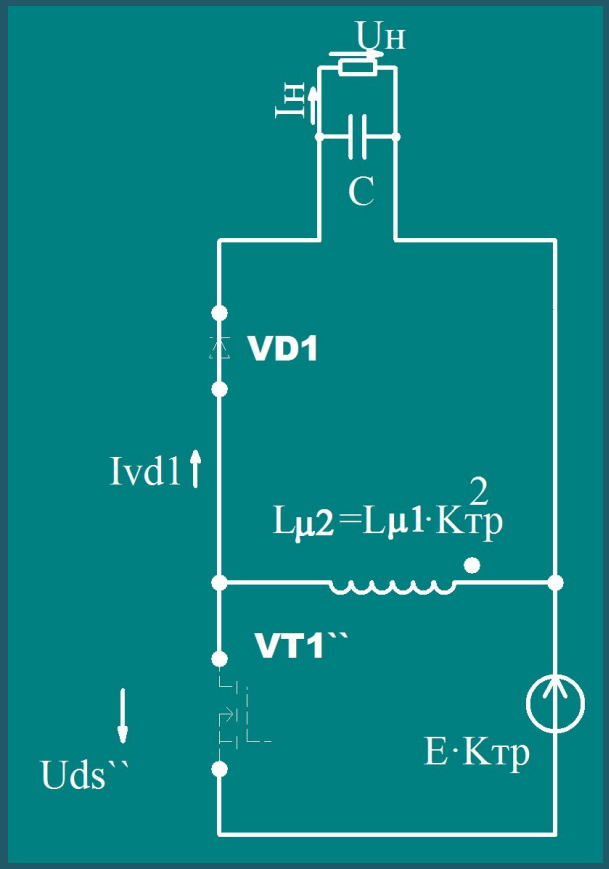
$$\Delta I_{L\mu 2} = I_{Lmax} - I_{Lmin} = \frac{E \cdot K_{тр}}{L\mu 2} \cdot t_и$$

Интервал паузы





Интервал паузы



$$\frac{d\,I_{L\mu 2}}{d\,t} = \frac{-U_н}{L\mu 2}$$

$$I_L(t) = I_{L\mu 2max} - \frac{U_н}{L\mu 2}\cdot(t - t_и)$$

$$I_{L\mu 2}(T) = I_{L\mu 2max} - \frac{U_н}{L\mu 2}\cdot(T - t_и) =$$

$$= I_{L\mu 2max} - \frac{U_н}{L\mu 2}\cdot(1-\gamma)\cdot T = I_{L\mu 2min} \quad (****)$$

$$\Delta I_{L\mu 2} = I_{L\mu 2max} - I_{L\mu 2min} = \frac{U_н}{L\mu 2}\cdot(t - t_и) =$$

$$= \frac{U_н}{L\mu 2}\cdot(1-\gamma)\cdot T$$

$$I_{L\mu 2min} + \frac{E\cdot K_{тр}}{L\mu 2}\cdot\gamma\cdot T - \frac{U_н}{L\mu 2}\cdot(1-\gamma)\cdot T = I_{L\mu 2min}$$

Напряжение нагрузки и ток Lμ

$$U_{н} = \frac{E \cdot K_{тр} \cdot \gamma}{1 - \gamma}$$

$$U_{ds\ max}`` = U_{н} + E \cdot K_{тр} = \frac{E \cdot K_{тр}}{1 - \gamma}$$

$$U_{ds\ max} = \frac{U_{ds\ max}``}{K_{тр}} = \frac{E}{1 - \gamma}$$

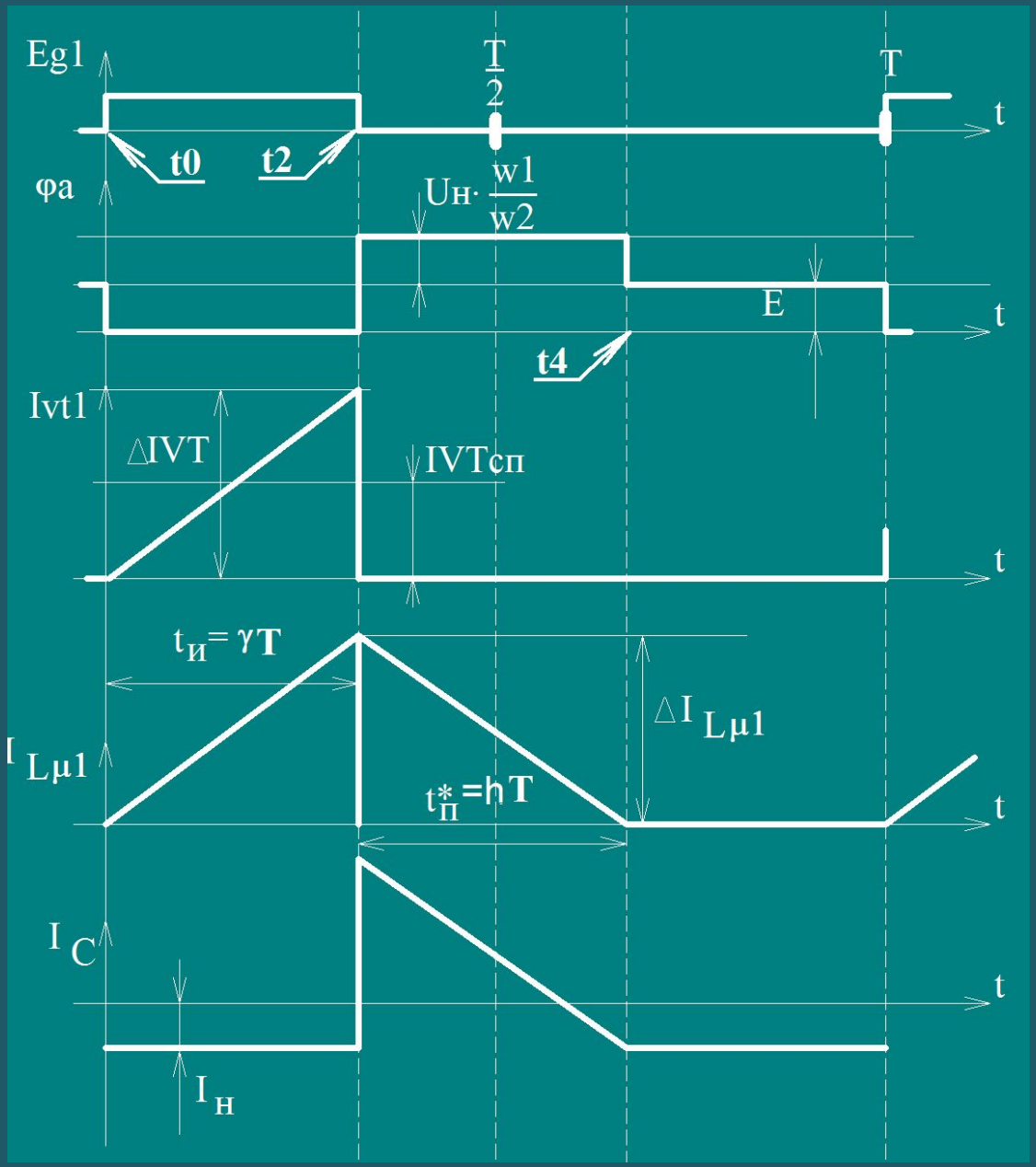
$$Qи = -I_{н\ ср} \cdot \gamma \cdot T = -I_{н} \cdot \gamma \cdot T$$
$$Qп = \left(I_{L\mu 2\ ср} - I_{н}\right) \cdot (1 - \gamma) \cdot T$$

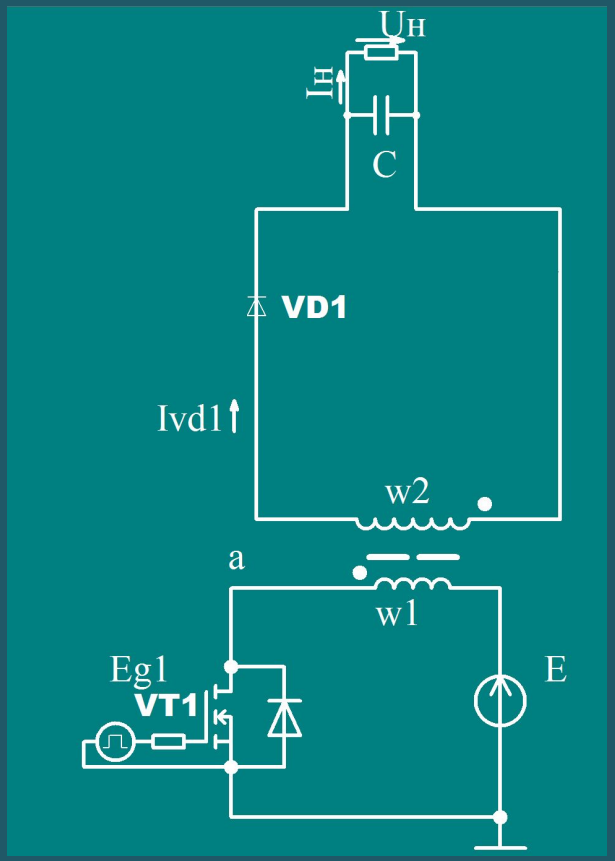
$$Qи + Qп = 0 \quad =>$$
$$-I_{н} \cdot \gamma \cdot T + \left(I_{L\mu 2\ ср} - I_{н}\right) \cdot (1 - \gamma) \cdot T = 0$$

$$I_{L\mu 2\ ср} = \frac{I_{н\ ср}}{1 - \gamma}$$

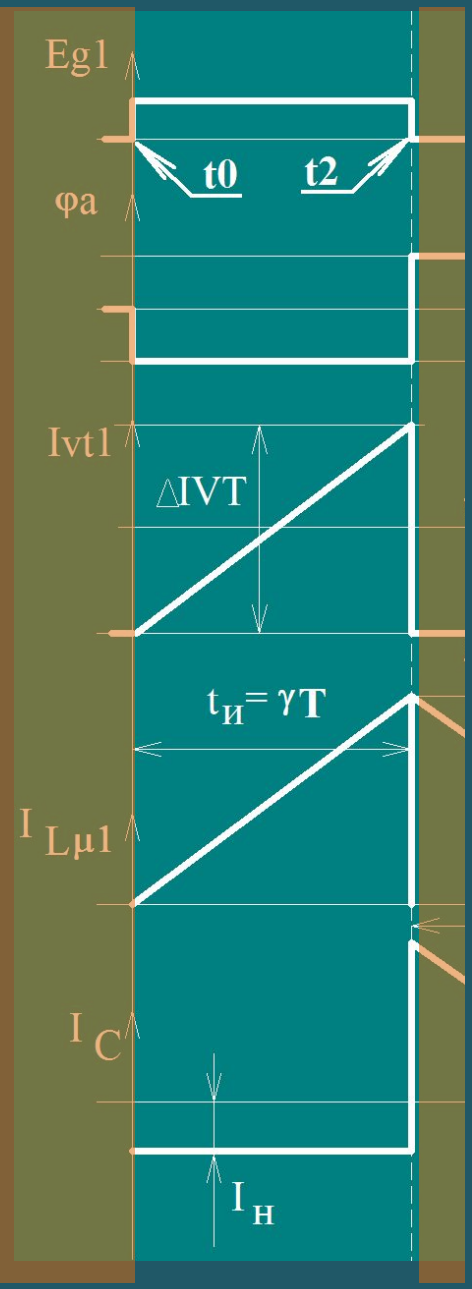
$$I_{L\mu 1\ ср} = \frac{I_{н\ ср} \cdot K_{тр}}{1 - \gamma}$$

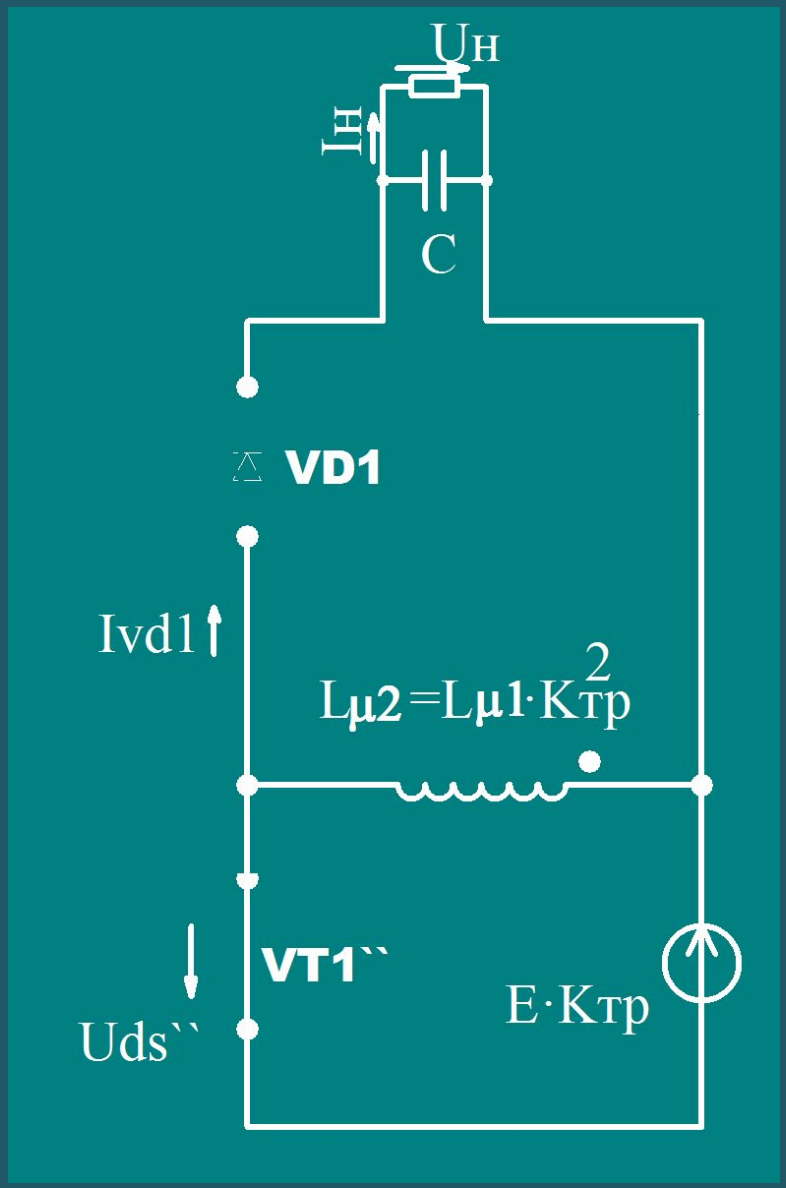
Режим разрывного тока



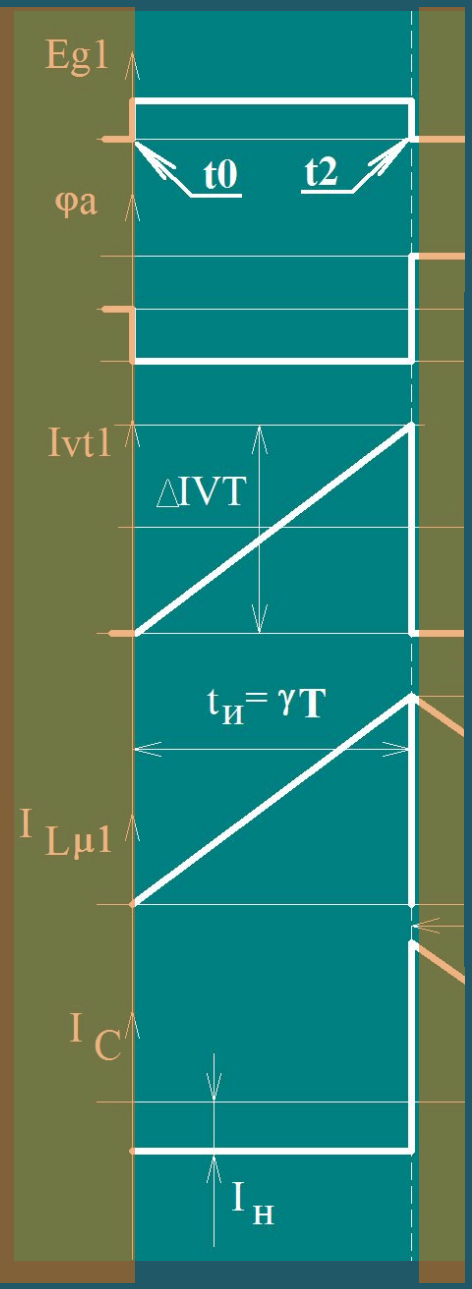


Интервал импульса





Интервал импульса

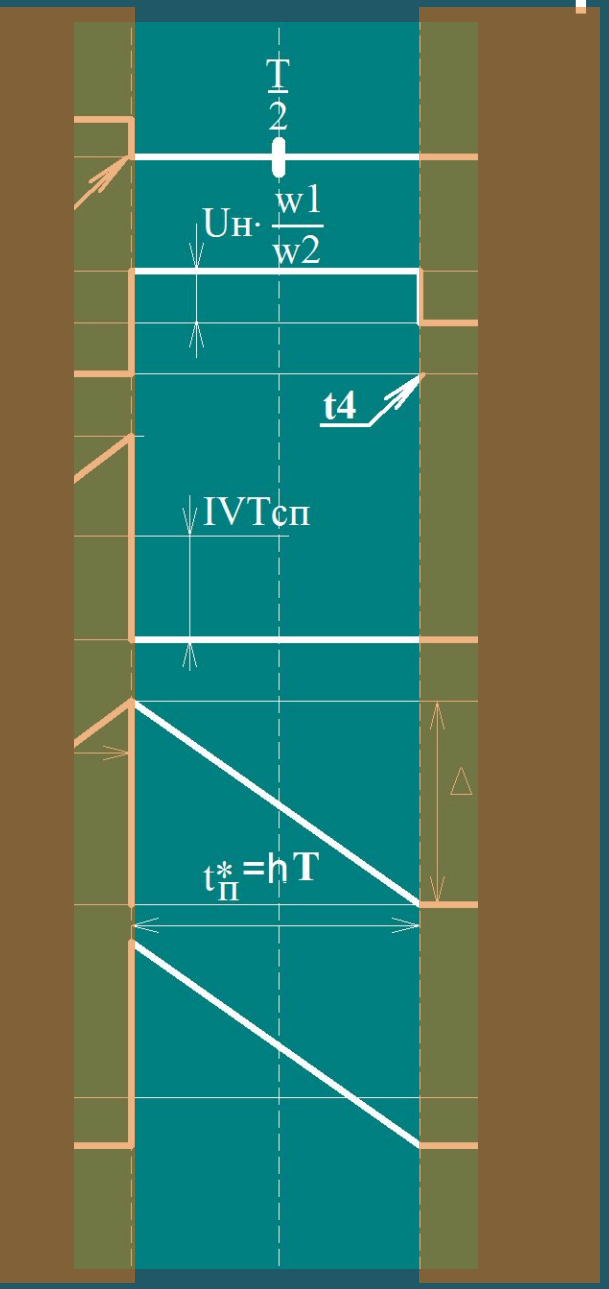


$$\frac{d\,I_{L\mu 2}}{d\,t} = \frac{E \cdot K_{\text{тр}}}{L\mu 2}$$

$$I_{L\mu 2}(t\text{и}) = \frac{E \cdot K_{\text{тр}}}{L\mu 2} \cdot t_{\text{и}} = \frac{E \cdot K_{\text{тр}}}{L\mu 2} \cdot \gamma \cdot T = I_{L\mu 2max}$$

$$\Delta I_{L\mu 2} = \frac{E \cdot K_{\text{тр}}}{L\mu 2} \cdot t_{\text{и}}$$

Интервал паузы с током



$$\frac{d\,I_{L\mu 2}}{d\,t} = \frac{-U_н}{L\mu 2}$$

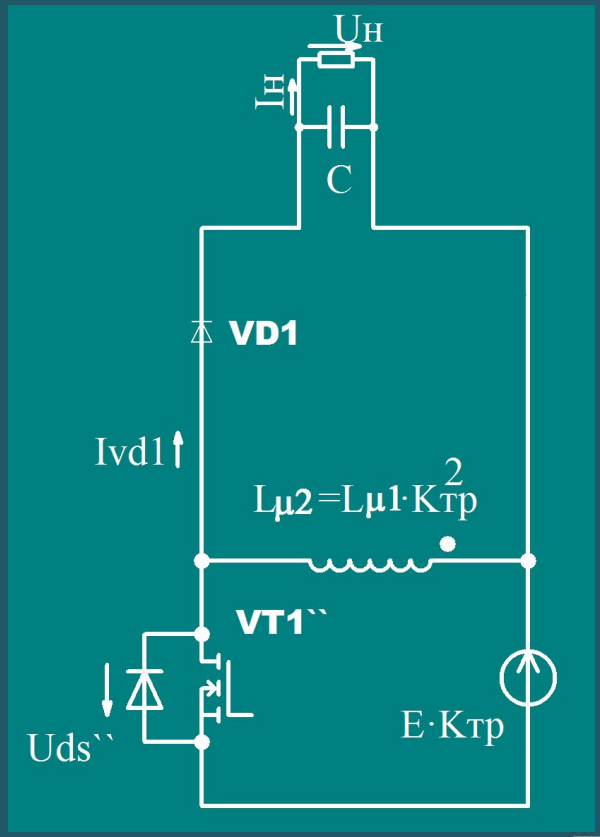
$$I_{L\mu 2}(t) = I_{L\mu 2max} - \frac{U_н}{L\mu 2} \cdot (t - \gamma \cdot T)$$

$$I_{L\mu 2}(t_и + t^*{}_п) = 0 = I_{L\mu 2max} - \frac{U_н}{L\mu 2} \cdot (h \cdot T - \gamma \cdot T)$$

$$\Delta I_{L\mu 2} = \frac{U_н}{L\mu 2} \cdot t^*{}_п$$

$$\frac{U_н}{L\mu 2} \cdot t^*{}_п = \frac{E \cdot K_{тр}}{L\mu 2} \cdot t_и \Rightarrow U_н \cdot h = E \cdot K_{тр} \cdot \gamma$$

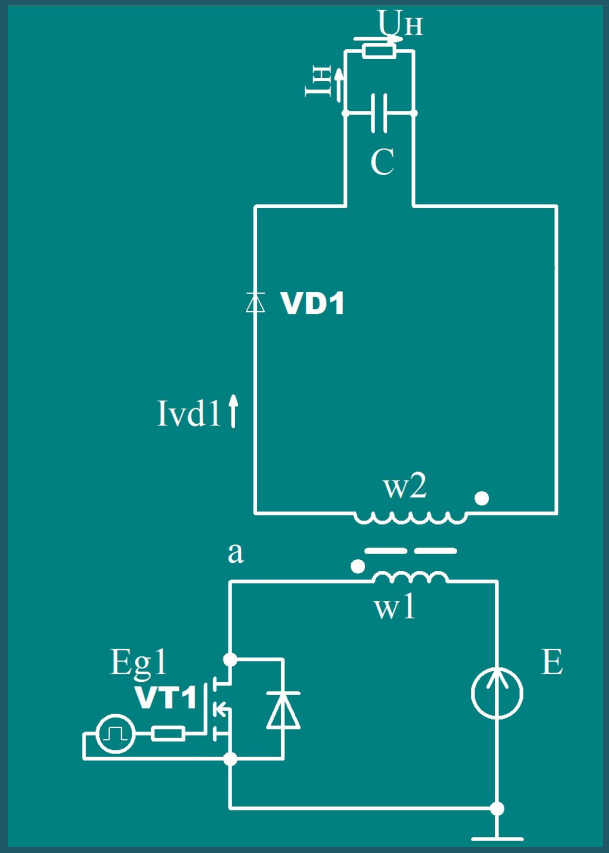
Средний ток диода



$$IVD1_{\text{СР}} = I_{\text{н ср}} = I_{\text{н}} = \frac{1}{T}\int_0^T ivd1(t)dt =$$

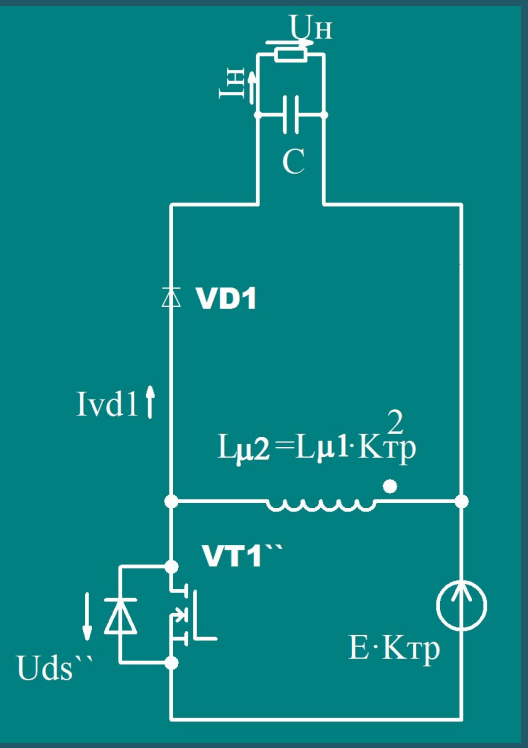
$$= \frac{1}{T}\left(\frac{\Delta I_{L\mu 2} \cdot h \cdot T}{2}\right) = \frac{E \cdot K_{\text{тр}}}{L\mu 2} \cdot \gamma \cdot T \cdot \frac{E \cdot K_{\text{тр}} \cdot \gamma}{U_{\text{н}}} \cdot \frac{1}{2}$$

Напряжение нагрузки



$$U_н = \frac{(E \cdot K_{тр})^2 \cdot \gamma^2}{2 \cdot L\mu 2 \cdot I_н} \cdot T = \frac{(E \cdot K_{тр})^2 \cdot \gamma^2}{2 \cdot L\mu 2 \cdot I_н \cdot f}$$

Напряжение нагрузки



Заметим:

$$I_{L\mu 2max} = \frac{E \cdot K_{\text{тр}}}{L\mu 2} \cdot \gamma \cdot T$$

Энергия, накопленная в $L\mu 2$:

$$\frac{L\mu 2 \cdot {I_{L\mu 2max}}^2}{2} = \frac{\left(E \cdot K_{\text{тр}}\right)^2 \cdot \gamma^2}{2 \cdot L\mu 2} \cdot T^2$$

Передаваемая мощность:

$$f \cdot \frac{L\mu 2 \cdot {I_{L\mu 2max}}^2}{2} = \frac{\left(E \cdot K_{\text{тр}}\right)^2 \cdot \gamma^2}{2 \cdot L\mu 2} \cdot T = U_{\text{н}} \cdot I_{\text{н}}$$

Отсюда:

$$U_{\text{н}} = \frac{\left(E \cdot K_{\text{тр}}\right)^2 \cdot \gamma^2}{2 \cdot L\mu 2 \cdot I_{\text{н}}} \cdot T$$